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WATER RESOURCES STUDY AND PUBLIC HEALTH ASPECTS OF THE SAN MIGUEL PROJECT COLORADO: STUDY OF POTENTIAL NEEDS AND VALUE OF WATER FOR THE PURPOSE OF WATER QUALITY CONTROL AND THE PUBLIC HEALTH ASPECTS OF THE SAN MIGUEL PROJECT, COLORADO

Public Health Service
Denver, Colorado

June 1964

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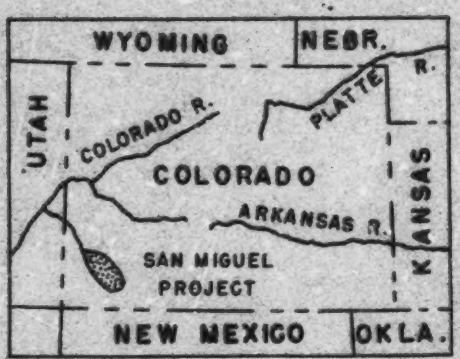
WATER RESOURCES STUDY
and
PUBLIC HEALTH ASPECTS
of the
SAN MIGUEL PROJECT
COLORADO



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WATER RESOURCES STUDY
and
PUBLIC HEALTH ASPECTS
of the
SAN MIGUEL PROJECT, COLORADO

Study of potential needs and value of water for the purpose of water quality control and the public health aspects of the San Miguel Project, Colorado.

Prepared at the request of and in cooperation with the Bureau of Reclamation, Region 4, U. S. Department of the Interior, Salt Lake City, Utah

U. S. Department of Health, Education, and Welfare
Public Health Service
Division of Water Supply and Pollution Control
Region VIII
Denver, Colorado

June 1964

I

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June 1964

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INTRODUCTION

Authorization

In accordance with the memorandum of understanding dated September 28, 1956, between the Bureau of Reclamation, Region 4, Department of the Interior, and the Public Health Service, Department of Health, Education, and Welfare, consideration has been given to the general public health aspects of the Bureau of Reclamation's proposed San Miguel Project. A subsequent letter of authorization dated August 14, 1962, broadened the study to recognize Public Health Service responsibilities set forth in Section 2(b) of the Federal Water Pollution Control Act (Public Law 84-660, as amended by Public Law 87-88).

Purpose and Scope

The general objectives of this study are to assess the probable effects that the proposed project will have on water quality in streams and reservoirs of portions of Montrose and San Miguel Counties in southwestern Colorado; to ascertain the benefits resulting from changes in water quality; to assess the suitability of the water for proposed water uses; and to examine the need for regulation of streamflow for the purpose of water quality control. Need for streamflow regulation was studied not only in the light of present condition, but also under anticipated future condition in the San Miguel River Basin for the years 1985, 2010 and 2060.

The report includes the results of a study of general public health aspects and insect vector control of the project. The insect vector control section, prepared jointly by the Colorado State Department of Public Health and the Communicable Disease Center, Public Health Service, Greeley, Colorado, presents a preliminary evaluation of the insect vector problems that may be associated with the project.

Acknowledgements

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Durango Projects Office - Durango, Colorado

Colorado State Department of Public Health
Denver, Colorado

Union Carbide Nuclear Company
Uravan, Colorado

U. S. Department of Agriculture
Forest Service and Soil Conservation Service
Norwood, Colorado

San Miguel Basin State Bank
Norwood, Colorado

County Officials
Telluride, Colorado

PART A

WATER RESOURCES STUDY

I. SUMMARY AND CONCLUSIONS

Summary

1. The proposed San Miguel Project is a multipurpose project of the Bureau of Reclamation. It is located in San Miguel and Montrose Counties in southwestern Colorado. The proposed system of canals and reservoirs will intercept water from the upper San Miguel River Basin for supplemental and full service irrigation of lands in both the San Miguel River Basin and the Dolores River Basin. The area included in the San Miguel Project and known in this report as the study area includes the entire San Miguel Basin and that part of the Dolores River Basin containing Gypsum and East Paradox Valleys. The area below the confluence of the Dolores River and San Miguel River includes only a few farms and the town of Gateway, Colorado, which does not have a municipal water system.

2. The economy of the study area is dependent primarily upon agriculture and mining. The area is sparsely populated and isolated from market outlets, thus hampering development in all segments of the economy.

3. The major consumptive water use in the San Miguel Project area has been for irrigation. Water demands have been largely supplied by surface flows since ground water supplies are limited in the area.

4. The town of Telluride, Colorado, is presently discharging raw sewage to the San Miguel River just upstream of the proposed Telluride Reservoir. Action has been taken to improve the quality of the effluent of two industrial pollution sources. Natural salt brine discharges to the Dolores River in the vicinity of Paradox Valley create a pollution problem, particularly during low flow periods.

5. The quality of water of the San Miguel River above Naturita Creek is satisfactory for most uses. Water quality deteriorates from irrigation returns and natural drainages as the water moves downstream. Only the mill at Uravan uses surface water from the San Miguel River below Naturita Creek.

Conclusions

1. Future economic growth, although relatively limited, is dependent on the development of surface waters to meet anticipated needs. Population estimates for the study area show an increase from 8,419, in 1960 to 10,800 by 1985; 12,000 by 2010, and 14,600 by 2060.

2. Water quality in the San Miguel River Basin will not be significantly altered by the San Miguel Project. This results in part, from the fact that irrigation return flows from Dry Creek Basin will not return to the San Miguel River, but will be diverted to East Paradox and Gypsum Valleys for irrigating those lands. It is expected that new irrigation returns from both Gypsum Valley and East Paradox Valley will increase the total dissolved solids (TDS) loading in the Dolores up to its confluence with the San Miguel River by an estimated 28,500 tons per year during the irrigation season.

3. Unless the town of Telluride provides treatment of its sewage and moves the city dump from its present location, recreational uses of the proposed Telluride Reservoir will be impaired. Recent modifications in treatment for industrial wastes should eliminate present pollution problems, but this will have to be determined in the future.

4. The only use of surface water from the San Miguel River below the confluence with Naturita Creek is by the Union Carbide Nuclear Company. Water treatment costs for this firm are not expected to be altered by the proposed project. For the Dolores River below Paradox Valley to the Colorado River, there is presently no user of a significant quantity of water. Water temperature limits this area to little or no fishing activity. Since this study revealed no present or expected beneficial uses of river water below Uravan or Paradox Valley, there is no apparent need for inclusion of storage in the project reservoirs for regulation of streamflow for the purpose of water quality control.

5. Additional studies are necessary in the East Paradox Valley and Gypsum Valley to determine the exact effects on water quality resulting from the proposed agricultural irrigation. Also, methods for preventing salt brines from contaminating surface and ground waters should be further investigated. Although no detailed analysis was performed, a preliminary estimate was made of the effects of the Dolores and San Miguel Projects on the average annual TDS concentration in the Colorado River. The effects of both projects will result in an increase in TDS concentration of 4 percent in the Colorado River below its confluence with the Dolores. The effect of the San Miguel Project alone will be a TDS increase of 1½ percent.

6. Since this study has been made in advance of any comprehensive study of the Colorado River Basin, the findings presented in this report are preliminary and subject to revision upon completion of comprehensive studies for water supply and water quality management in the Colorado River Basin.

II. DESCRIPTION OF PROJECT AND STUDY AREA

Proposed Project Development

The San Miguel Project will develop waters from the San Miguel River and its tributaries for irrigation, recreation, and fish and wildlife conservation, and will also provide for flood control. The system of reservoirs and canals will provide supplemental water to 12,530 acres of land presently irrigated in the San Miguel Basin and full service water to 35,770 acres of additional land in both the San Miguel and Dolores River Basins. The reservoirs and areas of the proposed project are shown in the pull-out map at the end of this report, Figure 1. Present flows in the San Miguel River will be depleted by an average of 76,800 acre-feet annually by the San Miguel Project.

Description of the Study Area

The San Miguel Project is located in southwestern Colorado in the counties of Montrose and San Miguel. The study area includes the San Miguel River Basin and Gypsum and East Paradox Valleys in the Dolores River Basin. Principal towns include Telluride, Norwood, Naturita, Nucla, and Uravan. The San Miguel River is a tributary to the Dolores River which joins the Colorado River just west of the Colorado-Utah state line. The general physiography of the San Miguel River Basin is that of high mountains lowering to a broken plateau area with canyons and narrow valleys in the eastern portion of the Colorado Plateau Province. The soils were developed principally from Dakota sandstone and Mancos shale. Gypsum Valley soils are underlain with deposits of gypsum with outcrops of gypsum occurring at various places in the valley. Paradox Valley soils are underlain with thick deposits of gypsum and highly soluble salt. Dry Creek Basin contributes high concentrations of soluble salts derived from the Mancos shales. Therefore, salinity and alkalinity problems occur throughout the lower portions of the project area due to the type of geologic formations found. Except for lands lying principally in the center of Dry Creek Basin, the existing topography of project lands generally provides good surface drainage. The climate varies over the Basin but in general it is temperate and semiarid. Refer to Appendix A for a more detailed description.

III. THE ECONOMY OF THE STUDY AREA

The determination of probable future effects on water quality brought about by the proposed project requires, not only an understanding of the present situation in the study area, but also the effect of the resource base on future development.

Present

The study area for economic analysis includes all of San Miguel County and the western portion of Montrose County. The economy of the area is primarily dependent upon mining and agriculture. Mineral production has predominated in past development while agriculture has played a more stabilizing role. Although total value of mineral production exceeds the value of agricultural output, the latter has considerably more impact on local area income generation due to its internal sales and purchasing patterns. Local expenditures of the mineral industry are represented mainly in payrolls. Manufacturing is relatively unimportant to the economy of the area. Recreation, particularly in the upper basin area, has been of increasing importance. The remoteness of the area to major transportation facilities, market outlets and largely populated areas has contributed to the area's limited development.

The population of the study area has remained rural in character through the years. Approximately one-third of the population lived in small towns during the 20-year period, 1930-1950. By 1960, small towns accounted for 48 percent of total population (Table I). An overall population increase from 1950 to 1960 was the result of development of the uranium-vanadium mining industry. Rural farm population declined continuously from 1940 to 1960.

TABLE I

Population Trends, San Miguel Study Area 1930-1950

	1930	%	1940	%	1950	%	1960	%
Small Towns[1/]	1,032	30	2,112	33	1,854	34	4,040	48
Other Rural[2/]	2,396	70	4,284	67	3,633	66	4,379	52
Total Population	3,428		6,396		5,487		8,419	

1/ All 1,000 or less population
2/ Includes rural farm and rural nonfarm

Future

The economy of the study area is not expected to change to any great extent from its present limited industrial-type activity. Agriculture and mining will continue as the major basic industries. Agricultural employment is expected to more than double after development of the San Miguel Project. It will then level off, and eventually decline during the last half of the projection period (1960-2060). Expected increases in the mining industry will be influenced by improved prices and mining methods, continued production of uranium and vanadium, and the possible future production of fertilizers and chemicals from salt and potash deposits in the Paradox area. Increased employment in the commercial and government sectors of the economy will be influenced by overall population growth, increases in personal income, expanding government activities, and increased recreational activity. Outdoor recreation is expected to play an important part in the area's growth.

Population and labor force projections for the study area are shown in Table II.

TABLE II

Population and Labor Force Projections
San Miguel Study Area, 1960-2060

	1960	1985	2010	2060
Total Population	8,419	10,800	12,000	14,000
Total Labor Force	2,925	3,800	4,400	5,300

The expected industrial expansion and population growth in the study area during the projection period will result in an increase in the waste loadings discharged to the streams. The effects of expected economic change on stream quality are recognized and evaluated in this report. (Refer to Appendix B for a more detailed discussion of the economy of the study area.)

IV. WATER SUPPLY AND WASTE SOURCES

The majority of water used in the San Miguel Project area is derived from surface flows. Flows in the San Miguel River are similar to other western mountain streams in that high flows occur in late spring. Ground water in the area is limited and has not been considered a major source of water.

The major consumptive water use in the study area is for agricultural irrigation. Approximately 28,000 acres upstream of Uravan are presently irrigated. Consumptive use by agriculture is estimated at roughly 35,000 acre-feet (AF) per year. Municipal use of water is relatively minor with an estimated 1,200 AF withdrawn annually. Only the towns of Nucla and Naturita are dependent on water from the San Miguel River and these water intakes are upstream from Naturita Creek (a major irrigation return in the basin). Industrial use, at present, consists of the ore processing mills at Telluride and Uravan and a steam electric generating plant near Nucla. Consumptive industrial water use amounts to about 1,520 AF per year. The steam electric generating plant, however, is presently using a flow of about 100 cubic feet per second (cfs) for cooling purposes. Fishing activity has been limited to the tributaries in the upper reaches of the San Miguel River and the San Miguel River above Naturita Creek. Major water users are shown in Figure 2.

Pollution sources in the San Miguel River Basin are municipal waste discharges, industrial waste discharges (mining and ore processing), and irrigation return flows. The presence of certain geologic formations in the study area results in a substantial amount of natural pollution. In the past, the Idarado Mining Company has allowed cyanide to be discharged to the river which has caused a biological desert. Attempts to correct this situation were undertaken in the summer of 1963, however, the results of this action are not known. The town of Telluride discharges untreated municipal wastes to the river and maintains a city dump on the river bank. The remaining larger towns provide some form of sewage treatment (Figure 2). The Union Carbide Nuclear Mill at Uravan has in the past been a major polluter of the river below Uravan with partially treated chemical wastes. A new lagoon has been constructed by the Union Carbide Nuclear Company to exclude their wastes from the river, and it is planned that all present discharges to the river will be diverted to this new lagoon. The effectiveness of these measures has not yet been determined. (Refer to Appendix C for a more detailed explanation of of water supply)

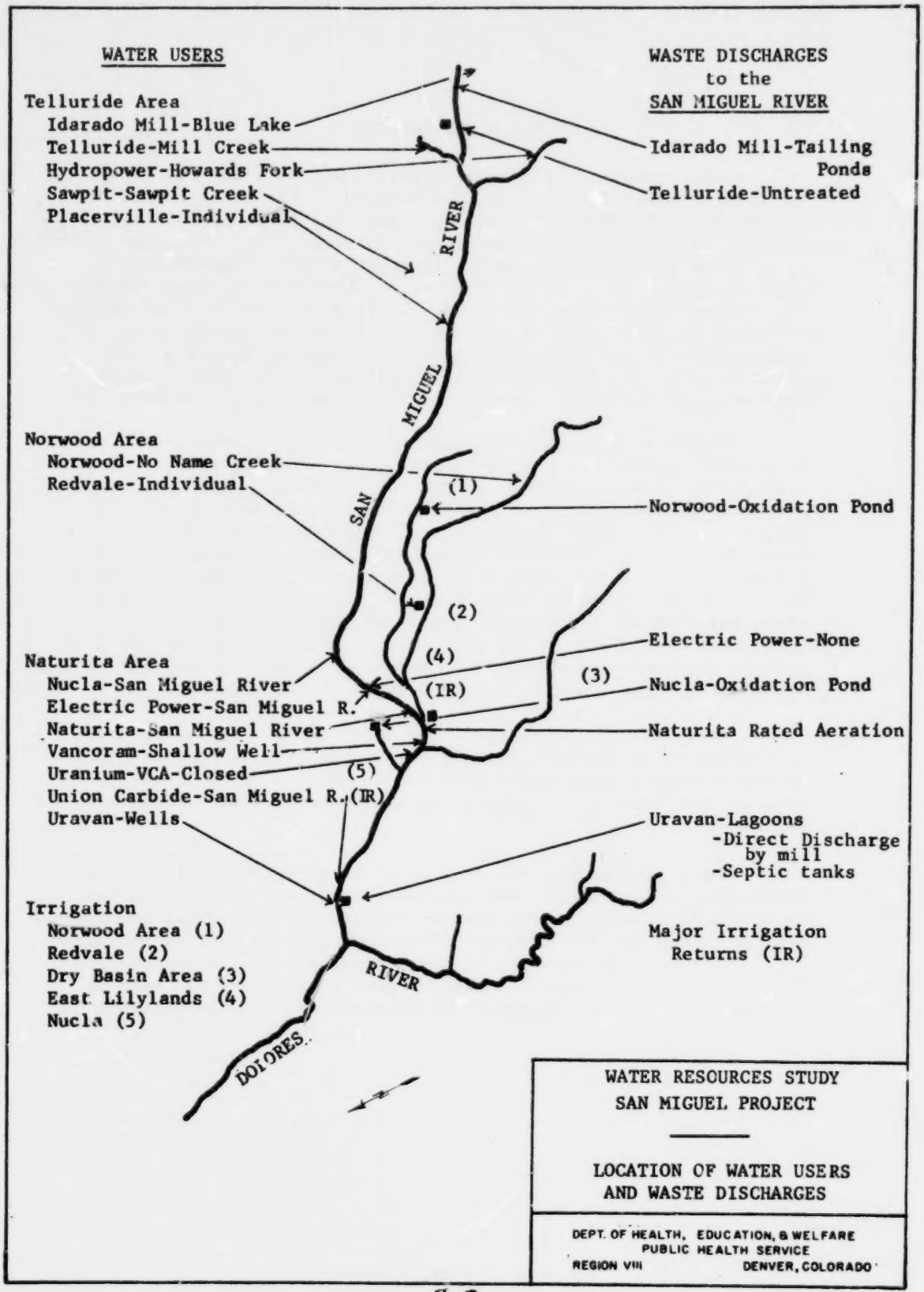

WATER USERS
Telluride Area
Idarado Mill-Blue Lake
Telluride-Mill Creek
Hydropower-Howards Fork
Sawpit-Sawpit Creek
Placerville-Individual
Norwood Area
Norwood-No Name Creek
Redvale-Individual
Naturita Area
Nucla-San Miguel River
Electric Power-San Miguel R.
Naturita-San Miguel River
Vancoram-Shallow Well
Uranium-VCA-Closed
Union Carbide-San Miguel R.
Uravan-Wells
Irrigation
Norwood Area (1)
Redvale (2)
Dry Basin Area (3)
East Lilylands (4)
Nucla (5)
WASTE DISCHARGES
to the
SAN MIGUEL RIVER
Idarado Mill-Tailing Ponds
Telluride-Untreated
Norwood-Oxidation Pond
Electric Power-None
Nucla-Oxidation Pond
Naturita Rated Aeration
Uravan-Lagoons
-Direct Discharge by mill
-Septic tanks
Major Irrigation Returns (IR)
SAN MIGUEL RIVER
DOLORES
(1)
(2)
(3)
(4)
(5)
(IR)
WATER RESOURCES STUDY
SAN MIGUEL PROJECT
LOCATION OF WATER USERS
AND WASTE DISCHARGES
DEPT. OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII
DENVER, COLORADO

Figure 2

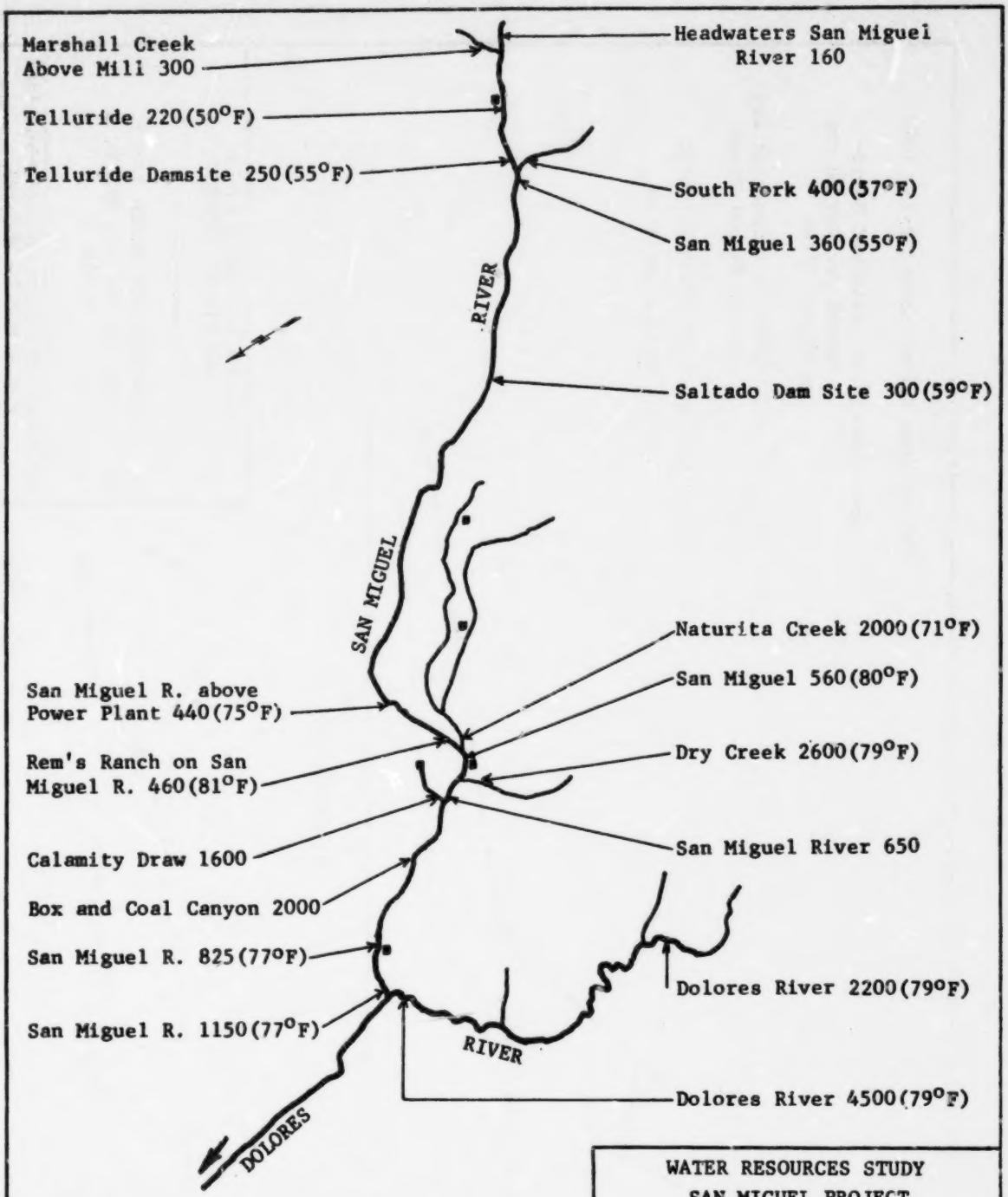
V. WATER QUALITY

Water quality varies considerably over both the San Miguel and the Dolores River Basins. An illustration of the variation in the San Miguel River Basin is shown in Figure 3. Although this figure contains only conductivity and temperature data for a one week period, it is valuable in that it exemplifies the gradual degradation of water quality. The effects of Naturita Creek and Dry Creek increase the conductivity in the main stem. It is felt that the high mineral pollution contributed by Dry Creek is a result of the influence of Mancos Shale in its drainage basin. The drainage basins of both Naturita Creek and Dry Creek are irrigated; and, therefore, these streams carry irrigation return flows of high mineral concentration.

Figure 4 serves to delineate those points at which the increase in mineral loadings on the San Miguel River are significant. Because straight lines were used to connect the points at which data was obtained the representation is not exact, but it does serve as an indicator of the location of the major mineral pollution loads. Naturita Creek and Dry Creek contribute relatively large mineral pollution loads. The increase in loading at Uravan was due mainly to the effluent from the Union Carbide Nuclear Company. However, since the time of the survey, corrective measures were taken by Union Carbide. Although the effect of these corrective measures has not yet been determined, one may presume that the increase in loading at Uravan will be smaller than that shown on the figure.

Table III is a summary of the water quality data collected by the Bureau of Reclamation. Of particular significance are the extremely high sulfate concentrations in the Dry Creek flows. It is felt that this is a result of the presence of Mancos Shale in the basin.

Table IV contains the results of an analysis designed to describe the variations in flows and concentrations by months at the three stations shown, under present conditions. The flows are average monthly values for the 20-year period from 1942 to 1961 as supplied by the Bureau of Reclamation in their "Analysis of Historic Runoff". The values of total dissolved solids were synthesized by means of curves describing the relationship between flows and concentrations.



NOTES: Conductivities as ($EC \times 10^6$ @ 25°C) u mhos/cm

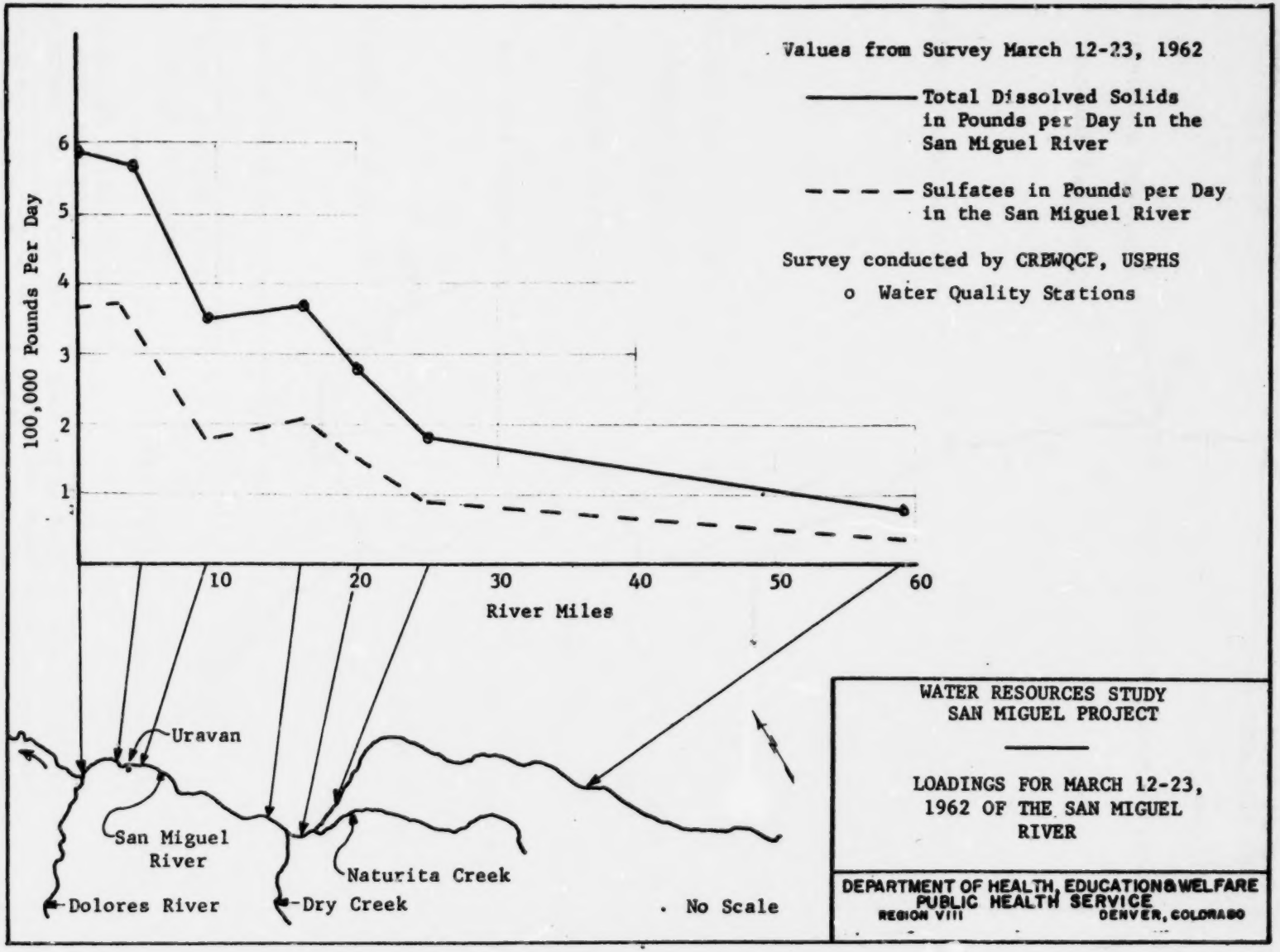
Temperatures and conductivity in most cases were obtained on the same day starting at Telluride and moving downstream. Flows are influenced by previous rainfall.

WATER RESOURCES STUDY
SAN MIGUEL PROJECT

WATER QUALITY FOR PERIOD
AUGUST 9-14, 1963
CONDUCTIVITY AND TEMPERATURE

DEPT. OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII DENVER, COLORADO

Figure 3


Values from Survey March 12-23, 1962
Total Dissolved Solids in Pounds per Day in the San Miguel River
Sulfates in Pounds per Day in the San Miguel River
Survey conducted by CREWQCP, USPHS
o Water Quality Stations
100,000 Pounds Per Day
6
5
4
3
2
1
10
20
30
40
50
60
River Miles
Uravan
San Miguel River
Dolores River
Dry Creek
Naturita Creek
No Scale
WATER RESOURCES STUDY
SAN MIGUEL PROJECT
LOADINGS FOR MARCH 12-23, 1962 OF THE SAN MIGUEL RIVER
DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII
DENVER, COLORADO

9-C

Figure 4

TABLE III

Chemical Quality of Surface Waters in Study Area

	Description	Number of Samples Taken		Esti-mated Flow cfs	ECx 10^6@ 25°C (u mho/cm)	TDS (salts) mg/l**	pH	%Na	SAR	Ca	Mg	Na	HCO_3	Cl	SO_4	Temp F
										mg/l						
1	San Miguel River near Telluride, Colorado (6/9/61-3/12/63)	(6)	Max	340	345	211	8.3	8.8	.2	56	5	7	103	2	91	54
			Min	14	174	117	8.0	6.9	.1	24	2	3	43	0	39	32
			WM*	--	193	131	--	--	--	29	3	3	48	0.7	49	--
2	San Miguel River near Placerville, Colorado (4/13/59-3/12/63)	(38)	Max	1,080	503	351	8.6	19.9	.7	86	16	21	200	7	176	64
			Min	41	210	133	7.9	4.1	.1	31	4	2	57	0	43	32
			WM	--	282	186	--	--	--	44	5	4	82	0.7	69	--
3	Dry Creek at Mouth near Naturita, Colorado (7/7/60-2/13/62)	(3)	Max	10	3,868	3,502	8.2	46.3	6.2	361	174	508	339	114	2,075	83
			Min	.05	3,589	3,458	7.7	32.5	3.9	250	154	361	155	78	1,920	69
			WM	--	3,593	3,502	--	--	--	359	174	363	157	79	2,073	--
4	Dry Creek at Old Coke Oven (5/28/62-9/28/62)	(5)	Max	45	4,445	4,324	8.0	38.0	5.5	370	213	536	232	114	2,624	63
			Min	.5	610	414	7.4	23.8	1.5	60	13	48	87	14	163	54
			WM	--	1,899	1,711	--	--	--	227	72	157	159	36	982	--
5	San Miguel River at Uravan (4/12/59-10/9/62)	(25)	Max	1,500	1,586	1,375	8.5	23.1	1.5	194	91	87	177	27	783	77
			Min	48	285	185	8.0	10.5	.3	38	7	7	89	2	60	32
			WM	--	496	356	--	--	--	61	19	17	111	5	160	--
6	San Miguel River at Mouth (9/15/60-10/9/62)	(10)	Max	1,500	3,376	2,992	8.3	--	39.2	282	165	234	110	219	1,484	72
			Min	62	420	263	4.1	--	12.1	42	10	12	0	5	67	43
			WM	--	707	510	--	--	--	64	24	44	72	43	228	--
7	Dolores River Above San Miguel River (4/13/59-9/15/60)	(6)	Max	480	57,767	41,664	8.4	90.6	122.4	415	336	13,800	166	22,026	2,113	84
			Min	2	512	316	7.6	33.5	1.3	49	10	39	114	60	48	56
			WM	--	4,126	2,497	--	--	--	75	31	781	126	1,196	259	--

Source: Bureau of Reclamation
*Weighted mean
**Milligrams per liter

Note: The Bureau of Reclamation considered only total dissolved salts and not total dissolved solids in their water quality analysis. For this area and in this report, the differences between these two analyses are considered negligible.

TABLE IV

Simulated Water Quality in the San Miguel River
under Present Conditions*

Month	Saltado Dam Site		Above Naturita Creek		At Uravan	
	Flow cfs	TDS mg/l	Flow cfs	TDS mg/l	Flow cfs	TDS mg/l
January	66	298	83	390	96	770
February	65	300	86	385	114	700
March	68	295	103	355	152	600
April	237	205	632	180	804	235
May	579	165	890	160	1095	220
June	815	160	888	160	1010	220
July	415	177	372	220	290	350
August	210	210	170	300	210	500
September	130	244	88	380	109	725
October	99	265	89	380	124	670
November	80	283	91	380	107	730
December	68	295	81	390	91	790
Average		241		307		543

*Note: Under data limitations these can be considered only as estimates

The results of this analysis indicate that during the late fall and winter months, where the flows are low, the concentrations of TDS are relatively high. During the late spring and early summer months, however, snowmelt results in a high runoff and an improvement in quality over the low flow months.

The increases in TDS between Saltado Dam Site and just above Naturita Creek are primarily of natural origin. Between Naturita Creek and Uravan, however, irrigation return flows of high mineral concentrations and natural pollution are the causes of the increase.

The water quality in the San Miguel Basin under present conditions is such that the water is generally satisfactory, after appropriate treatment, for its present water users. A notable and infrequent exception occurs when heavy sediment loads, which originate in the Dry Creek Basin, interfere with the use of water at the Union Carbide Nuclear Company at Uravan. Below Uravan the water is of relatively poor quality, but there are no further water users on the San Miguel River.

Below Uravan the San Miguel River joins the Dolores River. The latter is seriously polluted during low flows by discharges from the underlying brine aquifer as it passes through Paradox Valley. These brines increase the sodium and chloride ion content to 781 mg/l and 1,196 mg/l, respectively (Table III, Item 7). Analysis of the brine indicates a TDS of 257,000 mg/l, chloride of 160,000 mg/l, and sodium of 90,000 mg/l. All available data indicate that the quality in the Dolores River is generally poorer than the quality of the San Miguel. (Refer to Appendix D for a more detailed explanation of water quality.)

VI. EFFECT OF PROJECT OPERATION

The effects of project operations on water quality has been studied in three parts.

1. The effects of the operation of Saltado Reservoir on quality and flow below Saltado Dam.

2. The effects of changes in irrigation diversion patterns from below Saltado Dam to just above Naturita Creek.

3. The effects of increased irrigation in the Naturita Creek Drainage Basin and the diversion of the flows in Dry Creek to East Paradox and Gypsum Valleys.

One of the functions of Saltado Reservoir is to store the high spring runoff for agricultural use during the irrigation season. Inflows to the reservoir will be mixed with the water in storage. The overall effect of this mixing will be an improvement in the quality of outflows during low inflow months, and a slight deterioration of the quality of outflows during high inflow months. These conclusions were drawn from an analysis of the estimated mixing that would take place in an average year of reservoir operation. (This average year was derived from the Bureau of Reclamation's "Operation Study" for 1942-1961.) Estimates for the after project qualities and flows below Saltado Dam are shown in Table V.

The water stored in Saltado Reservoir for irrigation will be diverted from the reservoir through Norwood Tunnel. Part of this water will be used in Naturita Creek Drainage Basin and re-enter the San Miguel River as return flows in Naturita Creek. The remainder of the water diverted from Saltado Reservoir will be used in Dry Creek Basin and then diverted to Gypsum and East Paradox Valleys.

The reach of the San Miguel River from Saltado Dam Site to just above Naturita Creek will experience changes in irrigation diversion patterns. These changes will involve several ditches in the Beaver Creek area and the Colorado Cooperative Canal. During the irrigation season there will be an increase in diversions resulting in an outflow of TDS loading from this reach. This TDS loading will reappear as return flows in the reach of the San Miguel River between Naturita Creek and Uravan. The changes in diversion patterns within the reach can be considered in conjunction with the after project conditions at Saltado Dam Site to determine the resulting quality just above Naturita Creek. These values are presented in Table V.

TABLE V

Simulated Monthly Water Quality in the San Miguel River after Project Construction

Month	Below Saltado Dam Site Flow cfs	Below Saltado Dam Site TDS mg/l	Above Naturita Creek Flow cfs	Above Naturita Creek TDS mg/l	At Uravan Flow cfs	At Uravan TDS mg/l
January	31	230	57	395	86	745
February	36	240	65	380	106	675
March	37	245	81	350	143	370
April	91	250	449	180	633	200
May	195	235	410	185	652	255
June	252	250	257	235	432	400
July	159	200	67	355	128	865
August	111	180	41	385	120	730
September	89	190	40	405	99	690
October	49	200	44	470	101	650
November	25	215	47	435	89	720
December	24	225	47	430	76	795
Average		222		350		591

Note: Flow data obtained from Bureau of Reclamation reservoir operation studies.

The reach of the San Miguel from just above Naturita Creek to Uravan will experience the following after project changes:

1. An increase in return flows from Naturita Creek caused by additional irrigation which will be made possible as a result of project developments.

2. An increase in return flows from the Colorado Cooperative Canal.

3. A decrease in TDS loading as a result of the diversion of flows from Dry Creek to East Paradox and Gypsum Valleys for irrigation. The Dolores River between Gypsum Valley and the confluence with the San Miguel will eventually receive these flows in the form of irrigation returns (Estimated diverted TDS loading 28,500 tons/year).

The above changes were considered along with the after project conditions above Naturita Creek to determine the quality at Uravan as shown in Table V.

In the upper reaches of the San Miguel River (above the confluence of Naturita Creek) the average annual increase in TDS was estimated at 43 mg/l (i.e. from 307 mg/l to 350 mg/l). The corresponding increase in hardness was found to be 25 mg/l.

In the lower reach below Naturita Creek water treatment costs of the Union Carbide Nuclear Company are not expected to be increased. It is felt that any increase in softening costs due to increased hardness will be offset by the decrease in sediment load resulting from the diversion of the Dry Creek flows. Dry Creek, at times, has carried sediment loads high enough to seriously interfere with the Union Carbide plant's operations. When future conditions are such as to cause a release from Paradox Reservoir along Dry Creek to the San Miguel River, then the benefit of a decreased sediment load will not be realized. If the water released is of poor quality (any water of lesser quality than that in the San Miguel at the time of release), then the mill at Uravan would definitely have increased softening costs.

Most of the flow from Dry Creek Basin will be transferred for irrigation in Gypsum Valley and East Paradox Valley in the Dolores River Basin. The exact effect of irrigating soils overlying salt deposits in East Paradox Valley on water quality in the Dolores River is not known. However, the effect of the diversion from Dry Creek will be to increase the TDS load in this reach by 28,500 tons per year..

Brine discharges from the Paradox Valley presently produce high concentrations of dissolved solids in the Dolores River. Due to the complexity of this problem and the need for expanded investigations to identify and evaluate pollution sources, it is recommended that: (1) research be undertaken to determine methods for preventing contamination of surface and ground waters by brine discharged from Paradox Valley, and (2) investigations be made to determine the effects of present and proposed irrigation projects and transbasin diversions on water quality in the Dolores River.

VII. STREAMFLOW REGULATION REQUIREMENTS

Flows in the San Miguel River as projected by the Bureau of Reclamation will generally be lower than the present flows. This overall reduction in flows will result from increased use for irrigation (with accompanying evapotranspiration losses) and diversions from Dry Creek out of the San Miguel Basin.

The economic base study including projections and population growth for the years 1985, 2010, and 2060 has been used in determining future water requirements and waste discharges to surface waters in the study area for calculating minimum flows. Except for Telluride, Colorado, present sewage treatment facilities appear adequate. Dissolved oxygen concentrations are expected to remain above 5 mg/l, which is a concentration believed to be adequate for the maintenance of game fish. Assuming that all municipal wastes are adequately treated at their source, minimum flow requirements in the San Miguel River to assimilate the treated sewage effluent and to maintain dissolved oxygen concentrations of 5 mg/l were calculated. Under project operation minimum flows are expected to average well above minimum requirements during all months of the year.

As previously indicated, mineral concentrations in the San Miguel River will be increased under project operations. This increase will be due primarily to a reduction of flow brought about by evapotranspiration losses. Because of the limited municipal and industrial uses of the San Miguel's waters, no significant interference with water use is expected.

Under project operation the TDS load in the Dolores River between Paradox Valley and the confluence of the Dolores and San Miguel Rivers will be increased by an estimated 28,500 tons per year. The Bureau of Reclamation is also considering a project on the Dolores River upstream from Gypsum Valley (The Dolores Project) which will deplete the Dolores River flows by approximately 140,000 AF per year. This depletion will affect the water quality in the Dolores River.

The area below Uravan, Colorado, along the San Miguel River and below Paradox Valley along the Dolores River is populated by several farms and the town of Gateway, Colorado, which does not have a municipal water supply. The Colorado Department of Game and Fish reports that high temperatures in the lower Dolores River limits the fishing to a few Channel Cat. Therefore, there are no significant beneficial users of water in this area. The forecasted future

industrial and municipal expansion in the San Miguel study area will not be adversely affected by changes in water quality and related flow requirements in the San Miguel River caused by the project. Therefore, storage of water on the San Miguel River for regulation of streamflow for the purpose of water quality control is not considered necessary at this time.

A preliminary estimate of the cumulative effect on the water quality of the Colorado River, as a result of the proposed Bureau of Reclamation projects in the Dolores River Basin, was made by accounting for future changes in both salt load and annual flow at a point immediately below the confluence of the Dolores and Colorado River. If the depletion in flow resulting from the San Miguel Project and the depletion in flow and salt loading resulting from the Dolores Project are considered, then there will be an average annual increase of 4 percent in the TDS concentration of the Colorado River at a point below the confluence with the Dolores. If only the depletion in flow resulting from the San Miguel Project is considered, then this increase will be about 1½ percent. However, in all calculations no consideration was given to the possibility of an increase in the annual salt load as a result of irrigation in the Paradox Valley area.

Since this study has been made in advance of any comprehensive study of the Colorado River Basin, the findings presented in this report are preliminary and subject to revision upon completion of comprehensive studies for water supply and water quality management in the Colorado River Basin.

I. SUMMARY AND RECOMMENDATIONS

Summary

1. Project development will improve the economy and permit the establishment of a more healthful environment. Public Health services are provided in the project area by the Colorado State Department of Health.

2. Recreational development contiguous to reservoirs will be partially regulated by the topographical features of the shoreline.

3. Temporary construction camps may be necessary to serve the contractor's employees.

4. As overall watershed management involves many interests, it is essential that the affect on public health be fully coordinated with State and/or local health departments.

5. Mosquitoes are the principal vectors which might be affected by the proposed project, although other insects and rodents may be involved.

6. Encephalitis is the most important mosquito-borne disease in the United States and in the proposed project area. Equine encephalitis cases occurred in San Miguel and Montrose Counties during ten years of the period 1939 through 1955.

7. Extremely prolific production of mosquitoes has been found in meadowlands and roadside ditches in the vicinity of Norwood and Nucla.

8. Provision for the prevention and control of man-made vector sources will increase the overall benefits of the project.

Recommendations

Overall watershed management requires the cooperation of many interests to assure that development and activities will minimize the potential public health hazards associated with the proposed project. It is recommended that the following be given due consideration in development of the San Miguel Project:

1. That the water users' organization (i.e., Water Conservancy District) operating as the general administrative and contracting agency for the project should:

   a. Alert all water users of the potential public health hazards associated with using inadequately treated water for culinary purposes;

   b. Exert all possible precaution to exclude sewage effluents and barnyard drainage from project canals, laterals, and drains;

   c. Wherever and whenever possible assist the project inhabitants and communities in development of approved water and sewerage facilities;

   d. Operate and maintain project facilities in accordance with established criteria.

2. That potential recreational areas be investigated and at least minimum water and sanitary facilities be provided in accordance with Colorado State Department of Public Health.

3. That a sanitary survey of proposed construction campsites be made and all camps be provided with water and sanitary facilities in accordance with Colorado State Department of Health regulations.

4. That recreational activities at reservoirs utilized as a source of public water supplies meet the requirements established by the Colorado State Department of Health.

5. That person or persons responsible for a public water supply establish suitable controls over the use of watershed areas tributary to the supply to insure production of raw water meeting the quality requirements established by the Colorado State Department of Health.

6. Where applicable, the principles and practices for prevention and control of vector problems associated with reservoirs outlined in Appendix J be adhered to in the design, construction, and maintenance of the project.

7. Where applicable, the principles and practices for prevention and elimination of mosquito sources associated with irrigation outlined in Appendix K be adhered to in the development, operation, and maintenance of the project.

II. PUBLIC HEALTH AND RELATED PROBLEMS

Public Health Services

Project development will improve the economy of the area so that local residents benefiting either directly or indirectly will be in a position to enjoy a higher standard of living. Among other necessities, this involves the establishment of a healthful environment. Some of the more important factors in creating such an environment include the development of safe and ample culinary water supplies, proper waste disposal facilities, and insect and rodent control measures.

Public health services are provided in the project area by the Colorado State Department of Public Health.

Recreational Development

Concomitant with the development of water resources comes the increased use of lands adjoining reservoirs for recreational purposes. This presents major problems of sanitation involving those of coordination of the multiple use policy and prevention of water pollution. The extent of recreational development, planned or spontaneous, immediately contiguous to reservoirs will be partially regulated by the topographical features of the shoreline. Also, a receding shoreline during the irrigation season, together with an accumulation of mud deposits above the water level, will create hazardous and undesirable conditions for some water-based recreational activities.

Construction Phase of Project

Limited housing accommodations are available in the vicinity of construction sites in the San Miguel River Basin to serve the contractor's employees during the construction phase of the project. Under these conditions a temporary construction camp may be necessary. Prior to selection of a campsite a sanitary survey of the proposed area should be made by the State Department of Health or the Public Health Service to assist in solving of problems which may be encountered in connection with the installation of water and sanitary facilities.

Water supplies and sanitary facilities required in connection with temporary construction camps and with permanent housing for reservoir attendants should comply with the requirements of the Colorado State Department of Public Health so as to eliminate potential health hazards.

Sanitary Aspects of Watershed Management

As overall watershed management involves many interests, it is considered essential that proposed developments and activities on watersheds pertaining to public health aspects be fully coordinated with State and/or local health departments. These matters should be mutually considered prior to the actual development of the watershed and issuance of permits.

Adequate and safe water and sanitary waste disposal facilities, in accordance with State and/or local health agency standards, should be provided in public use areas to serve camping, picnicking, and other recreational uses. Water and sanitary facilities for private dwelling sites should also meet the established health standards. The effectiveness of the sanitation program should be evaluated periodically by a detailed sanitary survey in conjunction with laboratory analyses of water samples collected from surface and/or ground water in the watershed.

On reservoirs constructed primarily to serve as a source for a municipal water supply, extreme caution should be exercised in considering recreational use of the reservoir. This also involves the possibility of additional pollution entering the water supply and the matter of aesthetics.

Preliminary Vector Evaluation

Anticipated Effects of the Proposed Project on Vector Problems

Mosquitoes are the principal vectors which might be affected by the proposed project although other insects and rodents may be involved. Observations during June and July 1961, and July 1962, disclosed prolific production of Culex tarsalis, the encephalitis mosquito, and the vicious-biting Aedes dorsalis and Aedes vexans in roadside ditches and marshy pastures in the vicinity of Norwood and Nucla. In July 1962, production of Anopheles freeborni, the western malaria mosquito, and Culex tarsalis, was commonly observed in streambed pools along the San Miguel River between Uravan and Norwood. Basic information concerning pertinent biological characteristics of these mosquitoes is given in Appendix F.

Encephalitis, commonly known as sleeping sickness or brain fever, is now the most important mosquito-borne disease in the United States and the area in which the proposed project is located. Records of the U. S. Department of Agriculture show that the equine encephalitis cases occurred in Montrose and/or San Miguel Counties during ten years of the 17-year period 1939

through 1955 for which records are available. In Mesa and Delta Counties, which adjoin the northern border of Montrose County, 82 human encephalitis cases were reported during the six-year period 1952 through 1959. Additional information concerning the public health and socio-economic importance of mosquito and other vector problems associated with water resource developments is presented in Appendix G.

Impoundment of the upstream Telluride and Saltado Reservoirs on San Miguel River would provide minimum stream flows that should largely eliminate production of Culex tarsalis and Anopheles freeborni which occurs in streambed pools of the presently unregulated river during the low-flow period from mid-July to early fall. Storage of water in these reservoirs should also reduce early-season flooding of riverbottom areas between Norwood and Uravan and thereby be of great benefit in reducing aquatic habits favorable for production of the vicious-biting Aedes vexans. The portions of the proposed Telluride, Saltado, Naturita, Radium, Paradox, Pitchfork, and Miramonte Reservoirs that have shorelines with little or no vegetation and are exposed to wave action will be unfavorable for the production of mosquitoes and other aquatic insects of public health importance and will require no special vector prevention or control measures. Mosquito production may occur in tributary embayments and other marginal areas of the reservoirs where the water is shallow, protected from wave action, and contains emergent vegetation or flotage. Information concerning reservoir preparation, maintenance, and water level management in relation to mosquito prevention and control is presented in Appendix H.

Development of the proposed recreational and other public use areas in conjunction with the project reservoirs may result in the exposure of humans to vectors of terrestrial origin including arthopods such as ticks, fleas, and flies, and rodents such as ground squirrels, chipmunks and mice. In order to minimize public health hazards at waterside recreational areas, appropriate prevention and control measures for both aquatic and terrestrial vectors should be carried out.

At present, mosquito production in the Norwood area is largely associated with irrigation. The tendency of farmers to apply excessive amounts of water during early season when supplies are adequate, and the use of vegetation-choked roadside ditches as drainageways, result in numerous aquatic habits favorable for mosquito production. Development of the project and provision of a firm season-long supply of irrigation water should result in better irrigation practices throughout the project area and thereby benefit mosquito control. On the other hand, the provision of a larger supply of water for lands presently irrigated and the development of additional new irrigated areas may aggravate existing mosquito sources and create new aquatic habitats favorable for mosquito production unless appropriate prevention and control

measures are provided and continued as a part of the regular operation and maintenance. Pertinent information concerning the relationships between irrigation and mosquito sources are presented in Appendix I.

By making provision for the prevention and control of man-made vector sources, the overall benefits of the proposed project can be greatly increased.

Responsibility for Vector Control

Responsibility for vector prevention and control is normally associated with land ownership or operating rights. Therefore, the agency, group, or individuals responsible for various aspects of the proposed project should be prepared to accept full responsibility for the prevention and control of vector problems resulting from the design, construction, operation, or maintenance of the project.

BIBLIOGRAPHY

San Miguel Project, Colorado, Status Report, March 1953, Bureau of Reclamation, U.S. Department of Interior, Region 4, Salt Lake City, Utah

U.S. Bureau of Census, U.S. Census of Population, 1960, General Social and Economic Characteristics, Colorado, U.S. Government Printing Office, Washington, D.C.

U.S. Bureau of Census, U.S. Census of Agriculture, 1959, Vol. I, Counties, Part 41, Colorado, U.S. Government Printing Office, Washington, D.C.

U.S. Bureau of Census, U.S. Census of Agriculture, 1959, Vol. III, Irrigation of Agricultural Lands, U.S. Government Printing Office, Washington, D.C.

Personal Communication, District Forest Ranger, Forest Service, U.S. Department of Agriculture, Norwood, Colorado

Annual Report, 1962, Colorado Bureau of Mines, Department of Natural Resources, Denver, Colorado

The Economic Potential of Western Colorado, 1953, Bureau of Business Research, University of Colorado, Boulder, Colorado

1960 Directory of Manufacturers for the Colorado River Basin, 1962, U.S. Department of Health, Education, and Welfare, Public Health Service, Colorado River Basin Water Quality Control Project, Denver, Colorado

Stream Surveys in Vicinity of Uranium Mills III Area of Uravan, Slick Rock, and Gateway, Colorado - August 1960, Project Report 4, Colorado River Basin Water Quality Control Project, U.S. Public Health Service, Region VIII, Denver, Colorado, September 1961

APPENDIX A

DESCRIPTION OF PROJECT AND STUDY AREA

Proposed Project Development

The San Miguel Project will develop waters from the San Miguel River and its tributaries for irrigation, recreation, flood control, and fish and wildlife conservation. The primary purpose of the project is to supply water for irrigation--12,530 acres will receive supplemental water and 35,770 acres will receive full service water.

Two reservoirs are to be located on the main stem of the San Miguel River. They will provide the major regulation and storage for the proposed system. The Telluride Reservoir, 26,300 acre-feet active storage, will be located just below Telluride, Colorado. Saltado Reservoir with an active storage of 64,800 acre-feet is to be located near Placerville, Colorado.

From Saltado Reservoir, project water would be released into the Norwood Canal and conveyed through a series of tunnels and siphons to a system of existing canals and proposed canals located on the mesa drained by Naturita Creek.

Water is presently diverted from Beaver and Naturita Creeks for use in the Norwood and Redvale areas. The project will deliver supplemental water to these areas and full service water will be delivered to land in and near the Lilylands area. The proposed Naturita Reservoir with an active storage of 8,200 acre-feet would supplement main stem storage and provide regulation of water to the remaining Lilylands area and the Dry Creek Basin area. Water from Naturita Reservoir will be delivered to Pitchfork and Paradox Reservoirs for further distribution. Pitchfork Reservoir will have an active storage of 3,000 acre-feet and provide water to Gypsum Valley, Dry Creek Basin, and Radium Reservoir. Paradox Reservoir with an active storage of 13,700 acre-feet will collect flows from Dry Creek Basin and Radium Reservoir for irrigating lands in East Paradox Valley.

The proposed San Miguel Project would reduce the flows of the San Miguel River below Saltado Dam by 102,900 acre-feet annually. The major irrigation return flows would be to Naturita Creek, East Paradox and Gypsum Valley. The net depletion of the flows of the Dolores River below the mouth of the San Miguel River would average 76,100 acre-feet annually.

Description of the Study Area

Location

The San Miguel Project is located in southwestern Colorado in the counties of Montrose and San Miguel. The San Miguel River Basin is a part of the Dolores River Basin and the Dolores River is a tributary of the Colorado River. The proposed project will irrigate lands draining into Naturita Creek and Dry Creek, tributaries to the San Miguel River; and Gypsum Creek and East Paradox Creek, tributaries to the Dolores River. The principal towns in the area are Telluride, Norwood, Naturita, Nucla, and Uravan. The upper watershed of the San Miguel River lies in the Uncompahgre and San Juan National Forests. The river originates in the San Miguel Mountains, an extension of the San Juan Mountains. Elevations range from over 14,000 feet in the high mountains to approximately 4,860 feet on the San Miguel River at its confluence with the Dolores River.

Physiography[1/]

The general physiography of the San Miguel River Basin is that of high mountains lowering to a broken plateau area with canyons and narrow valleys in the eastern portion of the Colorado Plateau Province. This area has the characteristic horizontal or inclined sedimentary strata whose surface has been modified by folding, faulting, and rapid natural erosion. East Paradox and Gypsum Valleys are deep narrow valleys lying along the axes of two separate collapsed anticlines where the strata have been deformed by the intrusion and expansion of masses of salt and gypsum. Dry Creek Basin lies in a syncline which is broad, shallow and enclosed. The San Miguel syncline has a series of sloping narrow mesas and deep canyons superimposed on it.

Salinity and Alkalinity[1/]

Salinity and alkalinity problems occur throughout the project area. High concentrations of soluble salts derived from the Mancos Shales occur principally in the Dry Creek Basin. Gypsum Valley soils, underlain with gypsum deposits, are generally low in soluble salts. Paradox Valley soils are underlain with thick deposits of highly soluble salt. Brine wells in Paradox Valley supply commercial needs which are transported both by truck and pipeline. Union Carbide Nuclear Company transports brine by pipeline to Uravan.

Soils

The soils of the project area have developed largely under the controlling influence of a continental, semiarid climate with a sparse vegetative cover. The soils, considered generally as residual and alluvial, were developed principally from Dakota sandstone and Mancos Shale. Based on location and geological formation, these soils may be grouped into three broad categories; (1) mesa soils, located in the Redvale and Lilylands areas, are residual in origin, and generally underlain by sandstone or cobble strata; (2) basin soils, located in the Dry Creek Basin, are generally underlain by Mancos Shale which is noted for its high salt content; and (3) valley soils, located in the East Paradox and Gypsum Valley areas, are predominantly alluvial. The Gypsum Valley soils are underlain with deposits of gypsum showing outcrops at various places in the valley. They are generally well aerated, well drained and low in soluble salts. The Paradox Valley soils, alluvium and residual component sections of the Cutler and Hermosa formations, are underlain with thick deposits of gypsum and highly soluble salt. Outcrops of these formations occur along the valley floor.

Drainage[1/]

In general, the existing topography of project lands provides good surface drainage. However, due to the heavier textured soils derived from Mancos Shale and their flat topography, some lands within the Dry Creek Basin provide poor internal drainage and reduce surface drainage. Nonarable lands and severe problem areas, however, would be excluded from the project.

Climate

The climate varies over the Basin as the topography influences the movement of the air masses. In general, the climate in the project area is temperate, and semiarid. Precipitation ranges from 11 inches in the west to over 30 inches in the mountainous section of the east. At the Norwood Weather Station annual precipitation averages 16 inches, the maximum annual precipitation recorded was 24.6 inches (1957) and the minimum was 8.88 inches (1956). The area can expect thunderstorms approximately 50 days out of each year followed by some flash flooding. Snowfall in the mountains varies from 40 inches to over 100 inches. Lake evaporation is approximately 36 inches annually. Temperature

variation in the lower elevations ranges from 35°F below zero to 105°F with a mean annual temperature of 45°F to 50°F. The growing season extends from the middle of May to the beginning of October in the lower elevations.

1/ San Miguel Project, Colorado, Status Report, March 1953, Bureau of Reclamation, U. S. Department of Interior, Region 4, Salt Lake City, Utah

APPENDIX B

THE ECONOMY OF THE STUDY AREA

Present

The study area for economic analysis includes all of San Miguel County and the western portion of Montrose County. The economy of the area is dependent primarily upon mining and agriculture. While mineral production has exerted a greater influence on the area's development, agricultural production has provided considerable stability to the overall economy. The total value of mineral production has exceeded the value of agricultural output, but the latter has more impact on local area income generation due to its internal sales and purchasing patterns. Local expenditures of the mineral industry are represented mainly in payrolls. Manufacturing has been a minor segment of the area's economy. Recreational activities, particularly in the upper basin area, have been increasing. The remoteness of the area to major transportation facilities, market outlets and largely populated areas contributes to the area's limited development.

Population Characteristics

The population has remained rural in character through the years. Approximately one-third of the population lived in small towns during the 20-year period, 1930-1950. By 1960 small towns, all of which had 1,000 or less population, accounted for 48 per cent of total population (Table B-1). Rural farm population declined continuously from 1940 to 1960. This downward trend in farm population, coupled with a large outmigration of young adults, was offset by a 53 per cent overall population increase during the period 1950 to 1960. Development of the uranium-vanadium mining industry during this period virtually brought the towns of Naturita and Uravan into existence. The educational level of the people, as reported in the 1960 census, was equal to that for the United States as a whole, but was less than the state of Colorado or the mountain states region. The median family income increased from about $3,000 in 1949 to about $5,000 in 1959 compared to about $3,100 and $5,800 respectively for the state of Colorado.

TABLE B-1

Population Trends, San Miguel Study Area, 1930-1960

	1930	1940	1950	1960
Urban	--	--	--	--
Rural	3,428	6,396	5,487	8,419
Small Towns				
Norwood	299	412	294	443
Telluride	512	1,337	1,101	677
Naturita	--	--	--	979
Nucla	221	361	457	906
Uravan	--	--	--	1,005
Total	1,032 (30%)	2,112 (33%)	1,854 (34%)	4,040 (48%)
Other[1/]	2,396 (70%)	4,284 (67%)	3,633 (66%)	4,379 (52%)
Total Population	3,428 (100%)	6,396 (100%)	5,487 (100%)	8,419 (100%)

1/ Includes farm and non-farm population

Source: U. S. Census of Population

Labor Force Characteristics

The total labor force in 1960 was estimated at 2,925 persons, with unemployment accounting for six percent of the total. In 1960 the mining industry provided employment for 45.6 percent of the labor force; agriculture, 6.8 percent; manufacturing, 1.3 percent; construction, 3.7 percent; and government 9.7 percent. The secondary industries ranked as follows; retail and wholesale trades, 12.1 percent; transportation-utilities, 5.0 percent; services, 4.3 percent; and finance and real estate, 2.9 percent.[1] The development of the uranium-vanadium industry, beginning in about 1950, brought about major increases in employment for the mining and transportation sectors; however, the effect on construction activity was less pronounced. Persons employed in the commercial sectors increased, particularly in retail trade and finance, whereas agricultural employment declined from 1950 to 1960.

Land Use and Ownership

The study area includes approximately 1,400,000 acres about 45 percent of which is in private and state ownership. Federal lands make up the balance. The private and public range lands are devoted principally to grazing and mineral reservations while irrigated lands are used primarily for the production of hay and pasture.

Agriculture and Forestry

Agricultuml activity has centered around the Norwood, Redvale and Nucla areas where privately financed irrigation systems have been developed. The area is devoted almost exclusively to livestock farming (beef cattle and sheep), supported by irrigated crop production for feed. Estimated sales of livestock and other livestock products accounted for about 88 percent of the value of all farm products sold in 1959.[2] Total irrigated acreage amounted to 24,565 acres in 1949.[3] Due to inadequate water supplies and an increasing number of farm units becoming only part-time operations, the irrigated acreage declined to 19,600 acres by 1959.

National forest and Bureau of Land Management lands are generally utilized to full capacity by cattle and sheep ranchers. These lands provide essential supplemental grazing during the summer and fall months. In addition, the annual saw timber cut from national forest lands amounts to about three million board feet. The annual cut could be increased to five or six million board feet if market outlets were available.[4]

Minerals

Mineral production during 1962 included zinc, copper, lead, gold, silver, sand-gravel, iron, uranium and vanadium. Total value of all mineral production in the area during 1962 was about $37,791,000; uranium and vanadium accounted for just over 31 million dollars and other minerals about 6.6 million dollars. A post-war high of 9.6 million dollars for other minerals was reached in 1956.

Mining and milling operations of the Idarado Mining Company account for almost all activity in the production of zinc, copper, lead, gold and silver. These ores are processed at the Company's 1700-ton per day mill located east of Telluride. Increases in the price of silver had very little effect on silver production during 1962, however, it has stimulated interest in checking of old mining properties for future use. An increase in silver production would also increase lead and zinc production due to the complexity of the ores.

Uranium and vanadium producing areas are located throughout the western portion of the study area. Union Carbide Nuclear Company's plant located at Uravan processes raw ore both from Company and privately owned mines. The Vanadium Corporation of America closed its upgrading plant at Naturita early in 1963, but retains a maintenance crew at the plant. The Colorado Bureau of Mines established a District Office at Naturita in 1961 from which to direct the State Radiation Program.

Petroleum and gas prospecting in the area has met with little success thus far. Earlier tests did create interest in potential production from the Paradox Basin,[6] however, no oil production has been reported in this area.

Manufacturing

Manufacturing plays a limited role in the economy of the area. Sawmills and lumber related activities dominate the industry. Establishments reported in 1960 show 20 in lumber and wood products, one in food products, one in printing and publishing, and three in other non-resource oriented activities for a total of 27 firms.[7] Employment was provided for an estimated 38 owners and hired employees.

Outdoor Recreation

Except for hunting, which prevails throughout the study area, recreational activity is limited almost entirely to the upper basin. Major activities include jeep touring to historic townsites and mines, fishing, hiking, sight-seeing, skiing, camping, and hunting.

Trout Lake, at the headwaters of the South Fork of the San Miguel River, provides excellent fishing, boating, and other related activities. The historic mining town of Telluride, surrounded by the scenic beauty of the San Juan mountains, provides many interesting activities for tourists. An estimated 37,500 recreational visits (includes all activities) were made to the study area portion of the Uncompahgre National Forest in 1962.[4/] Considerable effort is being put forth by leaders and businessmen in the Telluride area to attract the tourist trade.

Tourist expenditures and related effects on the local economy are of increasing importance.

Commercial and Government Activities

Wholesale trade is of minor importance to the local economy. Retail trade, however, provided employment for approximately 11 percent of the total labor force during 1960. In 1960 transportation, communications, and utilities employed 5 percent of the labor force and the service industry employed 4.3 percent.

All commercial sectors show an increase in employment from 1950 to 1960 related primarily to the uranium-vanadium industry. Major increases occurred in the retail, finance, and service sectors.

The ratio of employment in the basic industries to employment in the secondary industries was 1 to 0.58 in 1960. The ratio of employment in the secondary industries is expected to increase with further industrial growth and particularly as a result of increased tourist-oriented activities.

The government sector employed almost 10 percent of the labor force in 1960. State and local governments accounted for the largest share of this employment.

Future

Future development in the study area is based on the general assumption that the nation and the Colorado River Basin will experience a relatively high level of employment and continued population growth.

Population and Labor Force

While total population increased by over 50 percent during the period 1950-1960, this trend is not expected for the future. Rather a slow but steady population growth related to overall economic activity is expected. Future employment in agriculture, particularly during the first half of the projection period, minerals, and the tourist-oriented industries are expected to be major contributors to a larger population.

The study area is expected to remain rural in nature throughout the projection period. Population trends and projections for the study area compared to the state of Colorado are shown in Figure B-1.

The economy of the study area is not expected to change to any great extent from its present limited industrial-type activity. Agriculture and mining will continue as the major basic industries. The number of unemployed persons is expected to drop from six percent of the labor force in 1960 to four percent by 1985, remaining at four percent thereafter. Projected population and labor force estimates are shown in Table B-II.

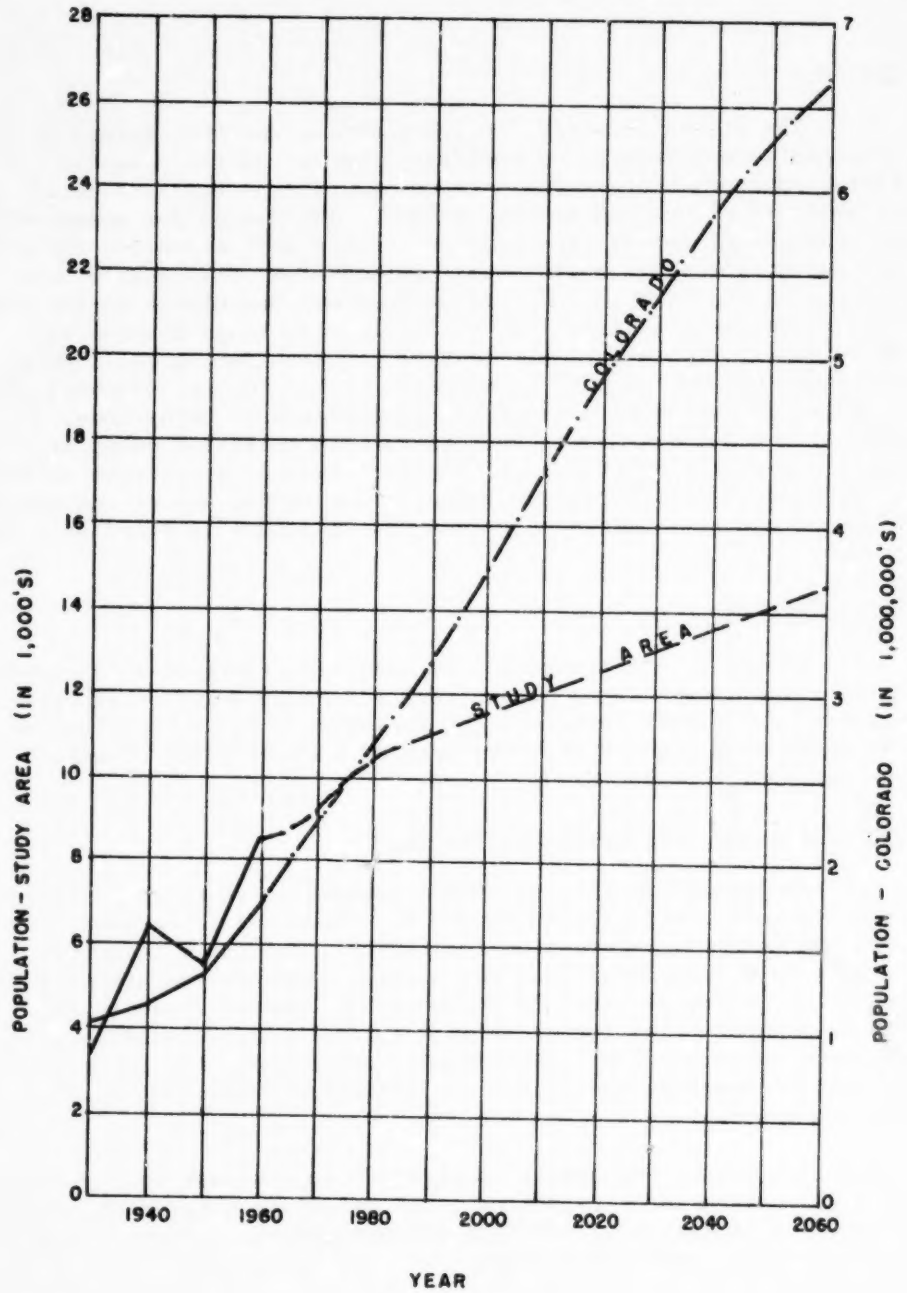
TABLE B-II

Population and Labor Force Projections,
San Miguel Study Area, 1960-2060

Area	1960 Number	1985 Number	2010 Number	2060 Number
Total population	8,419	10,800	12,000	14,600
Total labor force	2,925	3,800	4,400	5,300
Employed	2,750	3,648	4,224	5,088
Unemployed	175	152	176	212

Agriculture

Agricultural employment is expected to more than double the 1960 level with development of the San Miguel Project. The project will have the effect of reducing the size of farms with an increase in number. This effect is expected to carry well into the first half of the projection period because of location and adaptability of the area to agricultural and forestry activities. A change in the employment pattern with a movement out of agriculture will occur, similar to present state and national trends, but at a much later period in time.



SAN MIGUEL PROJECT
COLORADO

POPULATION

DEPT. OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE

FIGURE B-1

Minerals

The mining industry (includes mining and processing) is expected to continue as an important segment of the economy. Increased production in the base metals is expected as a result of improved prices and mining methods. The demand for nonmetallic mineral production is expected to increase with expansion in building and construction activities. In addition, developable salt and potash deposits in the Paradox area may contribute to the future production of fertilizers and chemicals. Although Uranium and vanadium production probably reached its peak during the 1960's, continued production can be expected for the future. Technological advances in the uranium industry are expected to bring about a substantial increase in the use of nuclear fuels for power production. The study area is in a highly favorable position to share in the future of the uranium industry due to the amount and quality of local ore reserves and the fact that vanadium is mined as a joint product.

Manufacturing

Growth in the manufacturing industry is expected to result mainly from expansion of present activities to serve local agricultural and timber markets. Manufacturing will be important to the study area, but is expected to play a minor role throughout the projection period.

Commercial and Government Activities

Employment in the commercial sectors is expected to increase relative to overall population growth, increases in personal income and increased recreational activity. The trade industry, largely retail oriented, and the service industry are expected to be the major contributors to future total commercial activity. The area's potential for additional outdoor recreational activity is expected to develop. The economic effects of this activity on most segments of the local economy will be important during the years ahead.

Government employment is expected to increase at a moderate rate as influenced by expanding local and state government activities, and expansion in planning and management of federal and state owned or controlled lands.

BIBLIOGRAPHY FOR APPENDIX B

SAN MIGUEL PROJECT, 1963

1. U. S. Bureau of Census, U. S. Census of Population, 1960, General Social and Economic Characteristics, Colorado, U. S. Government Printing Office, Washington, D. C.

2. U. S. Bureau of Census, U. S. Census of Agriculture, 1959, Vol. I, Counties, Part 41, Colorado, U. S. Government Printing Office, Washington, D. C.

3. U. S. Bureau of Census, U. S. Census of Agriculture, 1959, Vol. III, Irrigation of Agricultural Lands, U. S. Government Printing Office, Washington, D. C.

4. Personal Communication, District Forest Ranger, Forest Service, U. S. Department of Agriculture, Norwood, Colorado

5. Annual Report, 1962, Colorado Bureau of Mines, Department of Natural Resources, Denver, Colorado

6. The Economic Potential of Western Colorado, 1953, Bureau of Business Research, University of Colorado, Boulder, Colorado

7. 1960 Directory of Manufacturers for the Colorado River Basin, 1962, U. S. Department of Health, Education, and Welfare, Public Health Service, Colorado River Basin Water Quality Control Project, Denver, Colorado

Present total water demand by various users in the Basin is estimated to average 130,000 acre-feet annually as shown in Table C-II.

Instream uses, such as recreation and fishing, are virtually non-existent in the main stem of the San Miguel. Generally, fishing activity is limited to tributaries in the upper reaches of the San Miguel River where water is of suitable quality to support fish life.

Pollution Sources

Pollution sources in the San Miguel River Basin are derived from municipal waste discharges, industrial waste discharges (mining and ore processing), agricultural irrigation return flows and natural runoff. Table C-III presents municipal and industrial waste sources in the Basin.

The Idarado Mining Company's ore processing mill near the headwaters of the San Miguel River, separates zinc, lead, copper and amalgamated gold from about 1,700 tons of crude ore daily. Cyanide is used to depress the copper, and lime is used to control pH. Surplus water is discharged to Marshall Creek. The thickener effluent goes to a lagoon in the old tailings, and the remaining wastes go to the present tailings. All seepage from the tailings pond is held in a small lagoon next to the river bank before seeping to the river. This method of disposal has just been put into operation in an attempt to eliminate extensive cyanide pollution and the other toxic substances which resulted in a biological desert in the San Miguel River in the vicinity of Telluride. The effectiveness of the present lagooning procedure is now known at this time. Heavy rainstorms and snow slides result in sediments from the tailings piles being transported to the river. Acid mine drainage from abandoned mines drains to Marshall Creek and results in a low pH (Appendix D, Table D-III).

The town of Telluride discharges raw sewage directly to the river from two outfalls and maintains a city dump on the bank of the river. Both of these factors prevent instream uses of the San Miguel River and are aesthetically undesirable. The backwaters of the proposed Telluride Reservoir will reach the area of the dump.

TABLE C-II

Water Use - San Miguel River Basin

	Estimated Population	Source of Water Supply	Treatment	Estimated Use Acre-feet/Year
Municipal				
Trout Lake Area	Summer only	Fall Creek Canyon	None	3
Telluride Area				
Telluride	697	Mill Creek	None	120
Sawpit	40	Sawpit Creek	None	2
Placerville	60	Individual	--	9
	797			
Norwood Area				
Norwood	453	No Name Creek	Infiltration gallery, chlorination	102
Redvale	75	Individual	--	12
	528			
Naturita Area				
Nucla	906	San Miguel River	Sedimentation, chlorination	203
Naturita	979	San Miguel River	Sedimentation, chlorination	220
Uravan	1005	Wells	Chlorination	253
Vancoram	50	San Miguel River by shallow well	Chlorination	1
	2940			
Rural	4150	Individual (wells and cistern)		230
Total	8419			1154

TABLE C-II (Continued)
Water Use - San Miguel River Basin

	Employees	Source of Water Supply	Treatment	Consumptive	Demand
Industry					
Mining and Processing					
Pandora-Idarado	145	Blue Lake and Marshall Creek	None	19	2000
Naturita-VCA (closed)	15	San Miguel River	None and Softening		
Uravan-Union Carbide	370	San Miguel River	Clarification and Distillation	1180	3670
Strip Mining-Coal (Ophir area)	12	Unknown	Unknown	Unknown	Unknown
Mining (Independent Mines)	358	Unknown	Unknown	Unknown	Unknown
Electric Power					
Nucla-Steam	24	San Miguel River	None and Distillation	320	73,000
Ames-Hydro	2	Trout Lake	None	1	Unknown
				1520	78,670

Agriculture	Acres Irrigated	Source	Estimated Use Acre-feet/Year
Norwood Area	4640	Beaver Creek Surley and Cone Reservoir	Not available
Redvale Area	6140	Surley and Cone Reservoir	Not available
Dry Basin Area	1440	Dry Creek	Not available
East Lilylands	310	Callan Mud Springs	Not available
Nucla	8000	San Miguel River Colorado Cooperative Canal	Not available
Other	7470		Not available
	28,000		50,000

TOTALS

Municipal	1,154
Industry	78,670
Agriculture	50,000
	129,824 ≈ 130,000 acre-feet

TABLE C-III

Waste Sources in the San Miguel River Basin

Municipality or Industry	River Mileage	Sewered Population	Waste Treatment Provided	Estimated Waste Discharge* MGD	PE'S	Drainage to
Pandora-Idarado Mill	C1023.5 67.1-74.4	---	Tailing Ponds	.001	---	San Miguel River
Telluride	73.4	275	None	.74	700	San Miguel River
Ophir (Mill closed)	67.4- 7.9	---	Individual&Tailing Ponds	---	---	Howards Fork
Sawpit	65.4	---	Individual	---	---	San Miguel River
Placerville	61.6	---	Individual	---	---	San Miguel River
Nucla Generating Plant	24.3	---	None	28,800	---	San Miguel River
Norwood	23.3-19.2	400	Oxidation Ponds	.064	68	Naturita Creek
Redvale	23.3-10.8	---	Individual	---	---	Naturita Creek
Naturita	22.0	500	Packaged Aeration	0.137	250	San Miguel River
VCA Mill	20.2	---	Tailings Pond	(closed)	---	San Miguel River
Vancorum	19.2	50	Septic Tank	---	---	San Miguel River
Nucla	17.4- 4.8	500	Oxidation Ponds	0.127	136	Calamity Draw
Uravan	5.4	---	Septic Tank	---	---	San Miguel River
Union Carbide	5.4	---	Lagoons	0.6	---	San Miguel River

NOTES: *Waste Discharges for Municipalities Estimated at 70% of Water Use

River Mileage - C1023.5 - Colorado River to Confluence with Dolores
67.1 - Dolores River to Confluence with San Miguel
5.4 - Distance from Mouth of San Miguel
7.9 - Distance from San Miguel on Tributary

The present activities on the Hwards Fork of the San Miguel River are not expected to contribute greatly to the pollution problem. The mill at Ophir is closed, but there may be some drainage from the tailings at the mill. The hydro power plant at Ames, on Howards Fork, is presently in operation. Drainage from a "bog iron mine" was not investigated since there has not been noticeable effect on quality at the mouth of Howards Fork.

At the confluence of Leopard Creek and the San Miguel River at Placerville there are a few commercial establishments which could contribute some pollution. One cafe discharges wastes to Leopard Creek. It was also noted that an oil company has several storage tanks on the river bank. An oil leak from this operation would drain directly into the river.

Norwood and Redvale are located on a mesa to the south of the San Miguel River. Norwood has an oxidation pond, which discharges into Maverick Draw, a tributary of Naturita Creek. An irrigation ditch passes next to the lagoon and seepage or a dyke failure of the lagoon would discharge to the irrigation ditch.

The steam electric power plant located on the San Miguel River near Nucla discharges "once through" cooling water approximately $10^{\circ}F$ warmer than the receiving water in the stream. All other wastes are held in the plant area. There is a makeshift lagoon next to the river where coal washings have been deposited. These deposits would be picked up by flood flows if the lagoon dykes were overtopped.

From Naturita to the mouth of the San Miguel River, mineral pollution increases from irrigation return, natural runoff, and ore processing discharges at Uravan. Naturita has a rated aeration plant which, with proper operation, should be adequate for the present loadings. The Vanadium Corporation of America's plant at Naturita is presently closed down. However, if not properly cared for, old mill tailings next to the river could contribute large amounts of sediment to the San Miguel River.

The town of Nucla uses oxidation ponds for sewage treatment. While Nucla experienced problems with these lagoons initially, it is expected this treatment will be satisfactory. Calamity Draw drains the Nucla area entering the San Miguel River a short distance below the mouth of Dry Creek.

Following heavy rain or thunderstorm activity, Dry Creek discharges unusually high flows laden with silt and debris which seriously affects downstream use for normally short periods. Vancoram, a small group of apartments at the mouth of Dry Creek, uses a septic tank.

The Uravan Mill extracts uranium and vanadium from feed ores using an acid leach and ion exchange process.[1/] In the past, three separate effluents were discharged to the river. The mill is presently combining these effluents and plans to discharge them into a lagoon located across the river from the mill. The effectiveness of this treatment is unknown at present, but the Company expects that most of the constituents will precipitate out before returning (by seepage) to the river. The mill also uses a salt brine which is piped from Paradox Valley. There are several places along the pipeline where leaks were noted and salt brine was draining to the river. A break in this line could be a very serious pollution problem.

Agricultural irrigation return flows and natural runoff contribute to the pollution of the waters in the San Miguel River, but it would be difficult to determine the exact contribution by each.

1/ Stream Surveys in Vicinity of Uranium Mills III. Area of Uravan, Slick Rock, and Gateway, Colorado - August 1960, Project Report - 4, Colorado River Basin Water Quality Control Project, U. S. Public Health Service, Region VIII, Denver, Colorado, September 1961.

APPENDIX D

Water Quality

Water quality varies considerably over both the San Miguel River Basin and the Dolores River Basin. Evidence of this variability is illustrated by the data contained in the tables included in this section. The results from a two-week survey conducted by United States Public Health Service in March 1962, are shown in Table D-1. In this table the daily samples have been averaged for the two-week period. Table D-II shows the monthly variation in water quality at two points on the San Miguel River. These sampling stations were started April 1962 by the Public Health Service as a result of the Radiological Monitoring Network in the Colorado River Basin. Tables D-III and D-IV provide water quality data gathered during reconnaissance trips to the project area for the purpose of this report. A brief biological survey of the San Miguel River in the Telluride area was made in October 1962 by Public Health Service, Colorado River Basin Project personnel and is on file. This survey investigated the reported cyanide problem at Telluride, Colorado. Quality data from a survey conducted in August 1960 by the Public Health Service, Colorado River Basin Project, Denver, Colorado, is published in Stream Surveys in Vicinity of Uranium Mills, III. Area of Uravan, Slick Rock, and Gateway, Colorado - August 1960. Radiological pollution has not been nor is it expected to be a problem on the San Miguel River.

Generally, the waters of the upper basin of the San Miguel River are of good quality (item 2, Table III). During low flow periods mineral concentrations and hardness will increase (item 2, Table III), but these increases should not cause any interference with water use. With the recent changes in the Idarado Mill effluent, the problem of high cyanide and metals concentrations should be greatly reduced allowing the river to return to more natural conditions. However, if the toxicity problem should recur, then certain beneficial uses such as fishing will be eliminated. Recreational uses of the proposed Telluride Reservoir will be limited if the dumping of refuse and untreated sewage into the river by the town of Telluride continues.

Mine drainage to Marshall Creek and the effects on the San Miguel River are not a problem at present. The waters of the Howards Fork have increased chemical concentrations as the result of mining activity but again this is not large.

TABLE D-1

Water Quality Data for the San Miguel River Basin
March 12-23, 1962 - Collected by USPHS
(Values given are averages for sampling period)

		Est Avg Flow cfs	EC x 10^6 @ 25° C (u mhos/cm)	TDS mg/l	pH**	Total* Alk	Total* Hardness	Ca	Mg	Na	HCO_3	SO_4	Cl	Fe	Mn
								(Milligrams per Liter)							
1.	San Miguel River below Specie Creek ≈ 2.7 miles	50	450	303	7.8-8.1	110	290	94	13.8	5.9	135	140	1.6	0.1	0
2.	San Miguel River upstream of Naturita Creek	72	505	475	8.0-8.3	125	345	94	26.5	24.0	152	225	3.4	--	--
3.	Naturita Creek near Mouth	14	1904	1702	8.1-8.4	268	688	130	131	136	328	898	45	--	--
4.	San Miguel River upstream of Dry Creek	86	822	612	8.2-8.6	152	415	86	48	39	186	328	13	0.3	0.11
5.	Dry Creek near Mouth	12	3810	3940	7.6-8.4	210	1765	356	213	434	256	1765	108	--	--
6.	San Miguel River 2.3 miles below Dry Creek	87	952	788	8.1-8.6	154	535	121	56	56	188	424	16	--	--
7.	Tabeguache Creek near Mouth	5	586	342	8.0-8.4	232	255	61	25	34	284	60	38	--	--
8.	San Miguel River one mile upstream of Uravan	87	932	740	8.1-8.5	158	505	114	53	44	192	378	16	1.10	0.01
9.	San Miguel River two miles below Uravan	87	1610	1250	3.6-7.2	42	660	134	79	98	52	822	96	3.20	0.54
10.	San Miguel River near its Mouth	85	1660	1295	4.9-7.3	31	690	136	85	103	38	795	100	4.70	1.28

*As $CaCO_3$
**Range

TABLE D-II

Monthly Water Quality Data at Two Points on the San Miguel River

Date	ECx10^6 @ 25°C (u mhos/cm)	TDS	pH	Hardness As $CaCO_3$	Ca	Mg	Na	HCO_3	SO_4	Cl
					Mg/l					
San Miguel River above Naturita Creek (RMN 17)										
1962										
April	308	172	7.8	138	44	7.0	5.4	125	49	3.1
May	296	167	8.2	138	44	6.8	5.4	110	60	2.5
June	271	146	8.5	125	41	5.6	4.9	92	60	1.8
July	318	185	7.6	144	46	6.8	5.8	90	84	1.8
August	652	444	8.0	309	87	22.0	18.0	134	233	4.9
September	1120	852	8.0	569	142	52.0	37.0	170	493	8.6
October	496	318	8.2	234	73	12.0	12.4	127	153	3.4
November	534	356	8.4	251	77	14.0	14.0	134	162	4.8
December	487	325	8.3	234	75	11.0	11.0	130	144	4.0
1963										
January	485	307	7.8	225	71	11.0	11.0	124	138	4.3
February	495	360	8.6	233	73	12.0	11.3	138	138	3.0
March	419	294	8.0	193	62	9.5	8.3	131	103	1.9
April	369	250	8.2	169	53	9.0	7.9	130	78	1.0
May	304	188	7.2	136	45	5.8	5.6	94	69	1.8
June	346	211	7.3	153	49	7.3	6.9	91	90	1.8
July	680	480	7.3	313	90	22.0	21.0	146	229	5.0

TABLE D-LI (Continued)

Date	ECx10^6 @ 25°C (u mhos/cm)	TDS	pH	Hardness As $CaCO_3$	Ca	Mg	Na	HCO_3	SO_4	Cl
					Mg/l					
San Miguel River below Uravan, Colorado (RMN 20)										
1962										
April	488	329	7.7	211	59	15	15	117	127	12
May	518	350	7.8	221	60	17	17	102	151	11
June	488	341	7.9	208	56	16	15	78	154	10
July	635	450	7.1	267	65	25	23	30	246	17
August	1800	1340	4.6	667	129	84	84	1.6	858	83
September	2510	1980	4.8	1060	211	129	76	2.2	1270	114
October	1450	1050	6.6	573	122	65	65	35	652	57
November	1610	1120	5.4	567	111	70	81	3.6	724	76
December	1760	1270	4.6	578	119	68	86	1.0	828	84
1963										
January	1820	1340	5.9	703	154	78	95	I5	787	101
February	1780	1290	4.8	577	115	70	96	3.2	763	107
March	1210	861	5.8	488	117	48	50	16	492	44
April	800	568	7.8	331	87	28	32	74	271	27
May	687	455	7.8	278	70	25	29	84	225	21
June	786	530	6.9	316	77	30	33	22	304	26
July	1740	1450	7.3	811	217	65	93	158	796	43

Source: Colorado River Basin Project
United States Public Health Service

TABLE D-III

Water Quality Data for the Study Area from Reconnaissance Trips to the Area

	Description	Date	ECx10^6 @ 25°C (u mhos/cm)	TDS	pH	Total Hardness	Ca	Mg	Na	HCO_3	SO_4	Cl	K	NO_3
							Mg/l							
1	Marshall Creek just above Idarado Mill	10/11/62	617	--	5.6	278	89	14	6.8	2.4	310	0.5	--	--
		5/ 9/63	--	195	7.1	105	--	--	--	--	--	--	--	--
2	San Miguel River above Marshall Creek	10/11/62	480	--	7.7	230	88	2.4	4.3	54	194	0.5	--	--
		5/ 9/63	--	77	7.3	40	--	--	--	--	--	--	--	--
3	Idarado Mill effluent to Marshall Creek	8/10/63	400	255	7.0	176	64	4.1	6.8	49	156	1.3	--	--
4	Idarado Mill Tailings Seepage to the San Miguel	8/10/63	1080	786	7.0	402	160	0.7	45.0	40	492	6.2	--	--
5	San Miguel River just above Telluride at Campgrounds	5/ 9/63	--	155	7.4	107	--	--	--	--	--	--	--	--
6	San Miguel River at Highway 145 Bridge	10/11/62	348	--	7.6	156	55	4.4	6.2	89	96	0.5	--	--
		5/ 9/63	--	158	7.8	103	--	--	--	--	--	--	--	--
7	San Miguel River below Specie Creek	10/11/62	373	--	8.0	176	60	6.1	4.8	107	100	1.5	--	--
		5/ 9/63	--	197	7.8	116	--	--	--	--	--	--	--	--
8	Naturita Creek (Headwaters	5/ 9/63	--	330	8.0	236	--	--	--	--	--	--	--	--
	Naturita Creek (Mouth	8/14/63	2040	1690	8.0	902	181	109	142	264	932	43	--	--
9	Dry Creek near Mouth	8/13/63	2710	2230	7.9	949	220	97	276	219	1280	76	10	--
10	Calamity Draw near Mouth	8/14/63	1650	1370	7.8	887	202	93	52	239	777	8.8	3.2	-
11	Box and Coal Canyon Drainage	8/14/63	1980	1760	8.0	1200	271	128	36	189	1080	8.6	3.5	-

TABLE D-III (Continued)

	Description	Date	ECx10^6 @ 25°C (u mhos/cm)	TDS	pH	Total hardness	Ca	Mg	Na	HCO_3	SO_4	Cl	K	NO_3
							Mg/l							
	Water from Wells													
12	Uravan	3/15/62	1130	760	7.9	447	62	71	70	229	280	98	7.2	--
13	West Paradox Valley-irrigation pump approximately 1 mile west of Dolores River	8/11/63	2460	1920	7.4	1130	196	156	152	335	927	159	9.0	20.0
14	Gypsum Valley - Hand pump 100 ft. north of Dolores River	8/11/63	1640	1190	7.5	696	205	44	96	211	588	92	7.0	16.0

TABLE D-V

Analysis of brine sample from well in ground-water aquifer at Paradox Valley, Colorado

Well Location: SE 1/4, SE 1/4, Section 9, Range 18 West, Township 47 North, Montrose County, Colorado

Well owner: Union Carbide Nuclear Company
Uravan, Colorado

Depth of well: 70 feet (reported)

Discharge rate: 20 gpm (estimated)

Sample collected: 3/14/62 by S. J. Spiegel

Analyzed by Colorado River Project Laboratory, Salt Lake City, Utah

	ppm
Ca	687
Mg	2,520
Na	90,000
K	5,450
HCO_3	107
SO_4	88
Cl	160,000
SiO_2	16
Hardness as $CaCO_3$	11,100
TDS	257,000
Organic Carbon	5,170
Specific Conductivity ($EC \times 10^6$ @25°C)	208,000
pH	7.2
Ra-226	5.40uu g/l

APPENDIX E

BIOLOGY OF MOSQUITOES

This discussion is intended to provide only basic information concerning some of the more pertinent biological characteristics of mosquitoes commonly associated with water resource developments. These mosquitoes represent four important genera or groups: Anopheles, Culex, Aedes, and Psorophora. All mosquito species have four distinct stages in their life cycle: the egg, the larva, ("wiggler"), the pupa ("tumbler"), and the adult. A characteristic common to all mosquitoes is that they live in water continuously from the time the eggs hatch until the adults emerge. The aquatic stages generally occur in shallow water with an abundance of vegetation and flotage, and where they are protected from wave action. They do not occur in the deep open waters of lakes, ponds, or streams.

On the basis of egg-laying habits, mosquitoes may be divided into temporary-water and permanent-water species. The Aedes, and Psorophora are temporary water breeders which deposit their eggs on the moist soil of areas where surface water has receded. Hatching of the eggs is stimulated by subsequent floodings. The eggs may remain dormant for long periods, sometimes for several years if conditions are unfavorable for hatching. Normally, the eggs hatch more or less simultaneously soon after they are flooded. In contrast, the Anopheles and Culex usually lay their eggs on the surface of permanent and semipermanent bodies of water. The eggs usually hatch within a few days after oviposition. For both the temporary-water and permanent-water mosquitoes, time between hatching of eggs and emergence of adults varies with species and environmental conditions, especially water temperature. Development of the aquatic stages may be completed in as little as four days in hot weather while several weeks may be required in cool weather. Aedes and Psorophora mosquitoes generally develop more rapidly than the Anopheles and Culex.

Adult mosquitoes mate soon after emergence and the females begin seeking blood meals, which most species require before laying eggs. The biting habits of adult mosquitoes vary with species. Anopheles and Culex mosquitoes feed mainly at night while Aedes and Psorophora species feed both at night and in the daytime. Most species exhibit a peak of biting activity during a one- or two-hour period immediately after sundown. The Aedes and Psorophora species are aggressive and vicious biters of both man and livestock. Culex tarsalis, a vector of encephalitis, feeds readily on a wide range of hosts including man, wild and domestic birds, and livestock.

The flight range of mosquitoes varies widely with species and environmental conditions. The direction and distance of travel are greatly influenced by availability of food, shelter, and wind conditions.

Availability of food is probably the most important factor influencing the movement of mosquitoes in many areas. If an adequate food supply is close to the production sites, adult mosquitoes probably will not travel far from their sources. On the other hand, mosquitoes may travel several miles when adequate food supplies are not available nearer their larval habitats. The normal flight range of the Anopheles and Culex mosquitoes is usually considered to be about one mile, although recent studies have shown that certain species such as Culex tarsalis may travel several miles under certain environmental conditions. Most Aedes and Psorophora species are strong fliers and are known to range several miles from their larval habitats.

APPENDIX F

Public Health and Socio-Economic Importance of Vector Problems Associated with Water Resource Developments

Several groups of arthropods and rodents associated with the development and utilization of water resources may create serious public health and socio-economic problems. These include species that are vectors of disease organisms or serve as reservoirs of these organisms or which otherwise interfere with man's health and welfare.

Mosquitoes

Approximately a dozen species of mosquitoes of public health and socio-economic importance may be produced in habitats associated with irrigation, impoundments, and other water resource developments. Encephalitis, commonly known as sleeping sickness or brain fever, is now the most important mosquito-borne disease in the United States. Mosquitoes obtain the encephalitis viruses from wild vertebrates and then transmit them to horses and humans. There are no effective chemotherapeutic measures for preventing or treating human cases; and some individuals, particularly children, who recover from encephalitis often suffer permanent mental disability. Three principal types of mosquito-borne encephalitis occur in the United States. Eastern encephalitis (EE) occurs mainly in the Atlantic and Gulf Coast States from New Hampshire to Texas, but sometimes extends as far inland as Wisconsin. St. Louis encephalitis (SLE) occurs chiefly west of the Mississippi River and in several of the Central States. The third type, western encephalitis (WE), is confined primarily to the states west of the Mississippi River.

Culiseta melanura and several species of Aedes mosquitoes are believed to be involved in the transmission of EE. The principal vector of both WE and SLE in the Far West is Culex tarsalis, a mosquito which is widely distributed west of the Mississippi River. In the Central States, Culex pipiens and Culex quinquefasciatus are believed to be important in the transmission of SLE. Aedes and other mosquitoes may also be involved as secondary vectors of encephalitis. Both western and St. Louis encephalitis are endemic in many western areas, and outbreaks of WE among horses and of WE and SLE among humans have been rather widespread. In recent years, outbreaks of encephalitis have occurred in irrigated areas in the Texas High Plains (1956), in the Intermountain States (1957), in the Lower Rio Grande Valley (1957), in Utah and New Mexico (1958), and in Wyoming (1960).

The occurrence of malaria outbreaks as a result of improperly prepared reservoirs in the Southeastern States is well documented. Malaria has also been associated with irrigation in several states including California, New Mexico, Texas, and in the rice-growing areas of the Mississippi Delta. This disease has been almost eradicated from the United States; and at present, there is no significant malaria transmission anywhere in the Nation. The malaria vectors (Anopheles quadrimaculatus in the East and Anopheles freeborni in the West) are still prevalent in some areas where favorable habitats are present. These mosquitoes constitute a potential hazard for the establishment of new foci of malaria transmission, particularly in situations where the disease may be reintroduced from foreign countries. This was well illustrated at Lake Vera in California during the summer of 1952, where 35 cases of malaria occurred among Camp Fire Girls. The source of their infections was traced to a soldier who had an attack of malaria while camping at the lake.

Several vicious-biting species including Aedes vexans, Aedes dorsalis, and Aedes nigromaculis may be produced in habitats associated with irrigation and other water resource projects. These mosquitoes often create public health problems aside from the transmission of specific diseases. Such health hazards are illustrated by the results of surveys made by the United States Public Health Service in irrigated areas in northern Montana. In three-fourths of the families surveyed, mosquitoes severely annoyed both adults and children and interfered with their normal outdoor activities during the summer months. Mosquito bites causes some degree of injurious reaction in 8 out of 10 people interviewed; and in one section, 40% of the individuals examined by the physician showed evidence of secondary infection of mosquito bites. Some individuals, particularly children, frequently required medical attention and sometimes even hospitalization for treatment of secondary infections and occasional allergic reactions caused by mosquito bites.

In addition to their public health importance, mosquitoes often create other serious problems in both rural and urban areas. Their vicious biting reduces the efficiency of farm workers and sometimes hinders the harvesting of crops. Dense populations of attacking mosquitoes have been reported to kill livestock. The constant attacks of even moderate populations of these insects may reduce the vitality of farm animals and prevent proper feeding, thereby causing weight gains and lower milk and egg production. Mosquitoes are vectors of encephalitis, anaplasmosis, fowl pox, and several other important diseases of animals. These diseases kill large numbers of farm animals each years. Together, mosquito annoyance and mosquito-transmitted diseases undoubtedly result in losses of millions of dollars to farmers every year.

Large numbers of biting mosquitoes also cause serious economic losses by reducing the efficiency of industrial workers, lessening the value of real estate, restricting outdoor recreational activities, and reducing attendance at outdoor business establishments such as drive-in theatres and eating places.

The economic magnitude of the irrigation-mosquito problem alone is illustrated by expenditures for abatement of these insects. For example, in California over $5,000,000 is spent annually to control encephalitis and other irrigation mosquitoes and it has been estimated that at least twice this amount would be required to provide adequate control throughout the State. Approximately $200,000 is spend each year for mosquito abatement in a few irrigated areas in Utah. Many urban communities in other western irrigated areas spend large sums of money each season for chemical control to provide partial protection from mosquitoes. Individual families also spend sizable amounts of money each summer for household sprays, mosquito repellents, livestock sprays, and medicine for treatment of mosquito bites. The total cost of controlling irrigation mosquitoes, together with the other serious economic losses they cause, runs into many millions of dollars each year. Thus, mosquitoes are a major economic liability in many irrigated areas.

Other Aquatic Insects

Several other groups of aquatic insects may be produced in sufficient numbers in habitats associated with water resource projects to create public health and economic problems. Deer flies and horse flies (Tabanidae) are produced along the margins of impoundments and in seeps and marshes in irrigated areas. These insects are vicious biters of both man and livestock and are sometimes involved in the transmission of diseases such as tularemia and anthrax. Some species of small gnats of the family Heleidae are also vicious biters and often produce severe reactions and vesicular lesions. These gnats are produced in damp areas of many irrigated valleys as well as salt marshes and other wetland areas. In certain areas, black flies (Simuliidae) plague both man and livestock with their irritating and painful bites. They are normally produced in streams but sometimes occur in large numbers in irrigation conveyance systems. The small nonbiting midges (Tenipedidae) and the phantom midges (Chaoborinae) are another group of pestiferous insects which may be produced in impounded water. These insects are attracted to lights in tremendous numbers and cause severe human annoyance. An example is the Clear Lake gnat, Chaoborus astictopus, which creates serious problems at the resort areas in Lake County, California.

Terrestrial Arthropods and Rodents

Each summer, many millions of people visit picnic sites, campgrounds, cabins, and other water-related recreational facilities along the shores of reservoirs. In addition to mosquitoes and other insects of aquatic origin, these people are often exposed to terrestrial arthropods such as ticks, mites, fleas, and flies and rodents, including ground squirrels, rats, mice, and chipmunks. The public health importance of these arthropods and rodents involves a number of human diseases including Rocky Mountain spotted fever, Colorado tick fever, tularemia, relapsing fever, tick paralysis, typhus, plague, bacillary dysentery, and typhoid. The bites of certain arthropods also cause considerable irritation, discomfort, and annoyance.

APPENDIX G

Reservoir Preparation, Maintenance, and Water Level Management in Relation to Mosquito Prevention and Control

Man-made impoundments range in size from large multipurpose reservoirs with thousands of acres to small farm ponds of less than an acre. Mosquito-producing conditions associated with both large and small impoundments are basically similar but vary greatly in magnitude. They include emergent vegetation and/or floating debris in shallow water areas which are protected from wave action; undrained depressions, borrow pits, sloughs, and marshes within the summer fluctuation zone; and rising or constant pool levels which cause the water to remain in relatively flat areas with vegetation for more than four or five consecutive days during the mosquito production season. Several species of Anopheles and Culex mosquitoes, including Culex tarsalis, are frequently produced in impoundments that have protected shallow water areas with emergent vegetation and/or flotage. The flat vegetated areas of reservoirs and ponds, which are alternately inundated and exposed by fluctuating water levels, may also be highly favorable for the production of several species of Aedes and Psorophora mosquitoes. Aedes vexans is one of the most common and widespread of these species. It is almost axiomatic that reservoirs and ponds which are free of vegetation and flotage do not produce mosquitoes.

It is often difficult to control mosquito production on a reservoir that has not been properly prepared prior to impoundage. Clearing and drainage are the principal reservoir preparation measures for mosquito prevention and control. The overall objective of these measures is to prevent or minimize the development of favorable mosquito-producing habitats in any portion of the reservoir which is within flight range of human population.

Clearing includes removal of trees, underbrush, vines, fences, and debris from the reservoir basin. For mosquito control purposes, the normal summer fluctuation zone should be completely cleared except for isolated trees and sparse vegetation located along abrupt shorelines that will be exposed to wave action. It is not necessary to clear timber from the deeper portions of the reservoir basin where it will be completely submerged at normal summer minimum pool elevation. Timber rooted below the normal summer minimum pool level but extending above that elevation may be felled and securely tied down in lieu of disposal. This practice sometimes has advantages in fisheries management. Where clearing operations extend over several seasons, it is sometimes necessary to remove regrowth from the normal summer fluctuation zone immediately prior to impoundage.

Borrow pits, depressions, marshes, and sloughs which will be flooded when the reservoir is at maximum pool level and which will retain water at lower pool levels may be serious mosquito sources. Drainage ditches should be provided for all such areas, particularly those located within the normal summer fluctuation zone. These ditches should insure complete drainage of the areas when the reservoir recedes and permit fluctuation of water levels in them when the reservoir is at higher elevation. Such drainage ditches may also serve to prevent the stranding of fish when the lake recedes. Logs, drift, and other debris should be removed from natural drainageways and existing ditches where such work is indicated for mosquito prevention and control. Permanent shoreline improvement measures can sometimes be employed to eliminate mosquito-producing areas in reservoirs when the normal summer fluctuation zone is limited to a few feet.

Since the effectiveness of naturalistic, preventive, and permanent mosquito control measures is determined by the amount of clean water surface they create, it is essential that ponds and reservoirs be properly maintained after they have been impounded. Furthermore, maximum mosquito control benefits from water level management can be realized only when impoundments are properly prepared and maintained. Several phases of water level control, such as flood surcharge, constant level pool, cyclical fluctuation, and/or seasonal recession, can sometimes be adapted to various types of impoundments in order to minimize conditions favorable for mosquito production. Certain phases may be used to control vegetation and flotage or they may be used primarily to destroy mosquito larvae. A flood surcharge above the upper normal pool level for a few days in the spring prior to the mosquito production season followed by a sharp drawdown is effective in stranding objectionable flotage. The invasion of marginal vegetation can be limited by holding the reservoir at a constant level during the early spring growth period. This phase is especially important since it increases the effectiveness of subsequent fluctuation and/or recession. Seasonal water level recession alone or in combination with periodic fluctuation is an effective control measure since it provides a clean shoreline which is unfavorable for mosquito production. In some irrigation storage reservoirs, the normal water releases during the growing season usually result in a drawdown that keeps the pool level below encroaching marginal vegetation, thereby providing a clean shoreline that is unfavorable for mosquito production.

Recreational areas, especially those with facilities where people may remain overnight, should be located along sections of the reservoir which have the lowest potential for the production of mosquitoes and other aquatic insects of public health importance. Proper consideration should also be given to terrestrial vector problems in selecting recreational sites. Where necessary, full provision should be made for the prevention and control of both types of vector problems.

APPENDIX H

Relationships Between Irrigation and Mosquito Sources

The production of mosquitoes and other aquatic insects of public health importance occurs in many western irrigation areas, particularly where the water is applied by surface methods. Natural mosquito habitats are present in most irrigated areas, but usually man-made mosquito sources are far more important. These man-made aquatic habitats are frequently caused by the same faulty irrigation and drainage practices that result in serious soil and water problems such as excessive water losses, waterlogging, erosion, salt and alkali accumulations, damage to soil structure, leaching of plant nutrients, and reduced crop yields. Some of the "on-field" and "off-field" mosquito sources commonly associated with irrigation in the west are briefly discussed in the following sections.

On-Field Mosquito Sources

Prolific mosquito production occurs in low areas on fields used for pastures, hay meadows, and other close-growing forage crops where irrigation water often remains ponded long enough for the larvae to mature. Mosquitoes are sometimes produced on fields planted to irrigated row crops such as cotton, but usually ponded water is not present on these fields long enough for the aquatic stages to complete their development. Surface water must be present for at least 4 or 5 days in order for the aquatic stages to mature and produce adult mosquitoes. Rice is the only field crop that thrives when flooded this long. Observations in several areas have shown that when irrigation water is ponded on pastures and hay meadows long enough to produce mosquitoes, the desirable forage grasses and legumes are frequently killed and replaced by undesirable wetland plants. Thus, the extended flooding which is conducive to mosquito production is unfavorable for satisfactory growth of the common field crops.

In California, tremendous numbers of Aedes nigromaculis are produced in the ponded areas on irrigated pastures. Some of these pastures are irrigated 10 to 15 times from April through October and a brood of mosquitoes may be produced in the ponded water that remains after each irrigation. Investigations in the Milk River Valley of northern Montana showed that over two-thirds of all mosquito production (mostly Aedes dorsalis and Aedes vexans) on a 5,000-acre study area occurred in ponded areas on irrigated alfalfa fields, pastures, and western wheat grass meadows. In this valley, the irrigation water frequently remains ponded on the hay meadows long enough to produce Culex tarsalis, the encephalitis mosquito. Studies in Nebraska showed that large numbers of both Culex tarsalis and Aedes mosquitoes are produced in ponded areas on irrigated pastures and hay meadows along the North Platte River. The use of irrigated mountain

meadows for the production of hay and supplemental grazing of livestock is widespread in the Rocky Mountain States. In many of the mountain valleys, the bottomland meadows are flooded almost continuously throughout the spring and early summer months. Ponding also occurs in numerous low areas following irrigation later in the season. The extensive aquatic habitats that occur on many irrigated mountain meadows produce tremendous numbers of encephalitis and other irrigation mosquitoes.

In addition to the depressions on irrigated fields, water sometimes remains ponded in the field laterals and drains long enough to produce encephalitis and other irrigation mosquitoes. This type of mosquito source occurs most often in areas having fine textured soils and poor underdrainage. Field laterals and drains that contain excessive amounts of vegetation are more favorable for mosquito production. Mosquitoes may also be produced in the residual water in various hydraulic structures, such as drops in ditches, particularly when they contain tumbleweeds and other debris. Mosquito production in hydraulic structures is usually of minor importance in comparison with that which occurs in other types of "on-field" aquatic habitats.

Rice fields constitute a special type of "on-field" mosquito source, since the flooding used for growing rice is very favorable for mosquito production. In rice fields of the Mississippi Delta and Gulf Coast areas, large numbers of Psorophora confinnis and Psorophora discolor are produced by intermittent irrigation; and Anopheles quadrimaculatus, the malaria mosquito, is produced in the constantly flooded rice fields. Rice fields in California are usually flooded throughout the growing season and they provide favorable aquatic habitats for production of Culex tarsalis, the encephalitis mosquito, and Anopheles freeborni, the western malaria mosquito. Large numbers of Aedes nigromaculis and Aedes dorsalis mosquitoes are frequently produced by the initial flooding of rice fields in California.

Off-Field Mosquito Sources

In many western irrigated areas, widespread and prolific mosquito production occurs in a variety of aquatic habitats located outside the boundaries of irrigated fields. These mosquito sources include roadside ditches, borrow pits, depressions on nonirrigable land, and numerous other undrained areas that are flooded by surface runoff from irrigated fields and other excess irrigation water. Such aquatic habitats often contain dense vegetation which makes them more favorable for mosquito production. The semipermanent and permanent water areas are highly favorable for Culex tarsalis, the encephalitis mosquito. Those with fluctuating water levels produce large numbers of this mosquito as well as several vicious-biting Aedes species.

The types of "off-field" habitats just described accounted for more than one-fourth of the total mosquito production on a 5,000-acre study area in the Milk River Valley of northern Montana. In the North Platte Valley of western Nebraska, wasteland areas, roadside ditches, borrow pits and other undrained areas flooded by runoff from irrigated fields and overflow from conveyance systems were found to be important sources of both Culex tarsalis and Aedes mosquitoes. Playas or land-locked depressions, flooded by runoff from irrigated fields, were responsible for three-fourths of all mosquito production on study areas in the Texas High Plains. These playas produced large numbers of Culex tarsalis and several other species of irrigation mosquitoes. In certain western areas, large nonirrigable areas are wildly flooded with excess irrigation water for use by ducks and other waterfowl. Such areas are highly favorable for the production of tremendous numbers of Aedes mosquitoes. Several of the abatement districts in California and Utah spend large sums each year to control mosquitoes produced on waterfowl areas of this type.

Mosquito sources are often associated with the main irrigation conveyance systems, portions of which are sometimes located on nonirrigable lands. A large amount of irrigation water is often lost by seepage and leakage through the beds and banks of unlined canals and laterals which are located in pervious material. In areas having poor underdrainage, these seepage losses alone or in combination with deep percolation from irrigated fields often result in marshes and ponded water in roadside ditches, borrow pits, and other areas. In many western irrigated areas, aquatic habitats created by seepage produce large numbers of mosquitoes. Permanent and semipermanent seepage areas have been found to be especially favorable for the production of Culex tarsalis, a vector of encephalitis. Large numbers of Aedes mosquitoes are also produced in seepage areas that have fluctuating water levels.

Mosquito production may also occur in various other "off-field" aquatic habitats associated with the main irrigation conveyance systems. These mosquito sources include flooded areas resulting from overflow of poorly maintained canals and laterals; ponded areas where conveyance channels block natural drainageways; residual water in turnouts, stilling basins, and other hydraulic structures; surface pools created by leakage from water control structures; and residual water in conveyance channels during nonoperational periods. Although these types of aquatic habitat contribute to the total mosquito problem, they are generally of less importance than those caused by seepage and the numerous other "off-field" mosquito sources.

APPENDIX I

Principles and Practices for Prevention and Control of Vector Problems Associated with Reservoirs

I. Prevention and Source Reduction Measures

A. For Mosquitoes and Other Aquatic Insects

1. All borrow pits and other potential ponding areas associated with construction of the dam, relocation of highways or roads, etc., which are located above maximum pool level should be made self-draining.

2. Prior to impoundage, the reservoir basins should be prepared as follows:

   a. The normal summer fluctuation zone of the permanent pool should be completely cleared except for isolated trees and sparse vegetation along abrupt shorelines which will be exposed to wave action.

   b. Dense stands of timber rooted below the normal summer minimum pool level but extending above that elevation should be cleared. In some situations, such timber may be felled and securely tied down in lieu of disposal.

   c. Borrow pits, depressions, marshes, and sloughs which will be flooded by the reservoir at maximum pool level and which would retain water at lower pool levels should be provided with drains to insure complete drainage or fluctuation of water within them.

   d. If the summer fluctuation zone of the permanent pool is limited to a few feet, consideration should be given to "building out" mosquito-producing areas located within flight range of population groups or recreational areas through the use of measures such as deepening and/or filling. This would minimize the need for repetitive measures for controlling vegetation and mosquito production.

3. After impoundage, the following maintenance measures should be carried out in all potential mosquito-producing areas located within flight range of human population groups or recreational areas frequented by significant numbers of persons:

   a. All dense vegetation should be removed periodically from flat, protected areas within the normal summer fluctuation zone of the permanent pool.

b. Vegetation, debris, and flotage should be removed periodically from all drains to insure free flows.

4. Water level management to minimize conditions favorable for mosquito production should be used to the maximum degree permitted by the primary purposes of the reservoir. This will minimize the need for repetitive measures for controlling vegetation and mosquito production.

5. As a general principle, waterside recreational areas, particularly those which have facilities for overnight human occupancy, should be located along sections of the reservoir which have a low production potential for mosquitoes and other aquatic insects of public health importance.

B. For Terrestrial Arthropods and Rodents at Recreational Areas

1. Proper storage, collection, and disposal of refuse should be practiced in order to prevent and control flies, wasps, other noxious insects, rats, wild rodents, and other small mammals.

2. All buildings should be rodentproofed at recreational areas where rodents are prevalent which may create public health hazards.

3. Debris, rubbish, and other materials which may serve as harborage for rodents and other small mammals should be removed periodically.

4. Brush and weeds along paths, trails, roadways, and other areas of frequent use by visitors should be removed in order to reduce the likelihood of tick infestation.

II. Supplemental Chemical Control Measures

In situations where adequate vector control is not obtained through prevention and source reduction measures, provision should be made for supplemental use of insecticides and rodenticides to achieve the desired level of control.

III. Vector Appraisal

Arrangements should be made for carrying out a routine program of vector appraisal as a part of normal operations of the reservoir and associated recreational areas. Inspections for adult and larval mosquitoes and other vectors are essential for planning and evaluating control measures and for adjusting control programs to meet temporary or emergency situations.

APPENDIX J

Principles and Practices for Prevention and Elimination of Mosquito Sources Associated with Irrigation

A. Project Conveyance and Distribution Systems

1. Lining or other satisfactory seepage control measures should be provided for all sections of canals and laterals located in porous material where excessive leakage would result in waterlogged areas, seeps, and ponds.

2. Drains should be installed to prevent ponding of excess irrigation water and natural runoff along the upper side of canals and laterals. All drainage crossing or inlet structures should be placed on grade to avoid ponding.

3. Borrow areas should be self-draining to keep them from retaining ponded water.

4. Where possible, provision should be made to prevent turnouts and other hydraulic structures from retaining residual water when they are not being used.

5. Effective measures should be provided to prevent ponding of leakage from water control structures.

6. Every effort should be made to establish delivery schedules which will provide farmers with adequate but not excessive amounts of water at proper intervals to insure efficient irrigation of the crops concerned.

7. Vegetation and debris which would retard normal flows should be periodically removed from conveyance channels, water control structures, and drains.

B. Project Drainage Systems

1. Trunk drainage systems should be installed to insure complete removal and proper disposal of excess irrigation water, natural runoff, and seepage from both irrigable and nonirrigable lands affected by the distribution and use of irrigation water on the project.

2. Drainage ditches should be designed, constructed, and maintained so as to minimize ponding in the channels and to insure free flows at all times.

3. Provision should be made to prevent water from ponding behind spoil banks.

4. Underdrains, culverts, inlets, etc., should be placed on grade to prevent ponding.

C. Irrigated Farms

1. The sponsoring agency and other organizations concerned with irrigation agriculture or mosquito control should do everything possible to encourage irrigation farmers to use the following irrigation and drainage practices which will prevent or minimize mosquito sources:

   a. The farm supply system, drainage system, and field layouts should be properly fitted to the topography, soil, water supply, crops to be grown, and irrigation methods to be used.

   b. All surface irrigated fields should be properly leveled or graded to provide for efficient water application and removal of excess water without ponding.

   c. An adequate drainage system should be provided for removal of excess water from all portions of the farm.

   d. Irrigation methods should be used which will provide optimum irrigation efficiencies.

   e. Application of irrigation water should be limited to that required to fill the crop root zone plus unavoidable losses and excess water needed to prevent upward movement of salts.

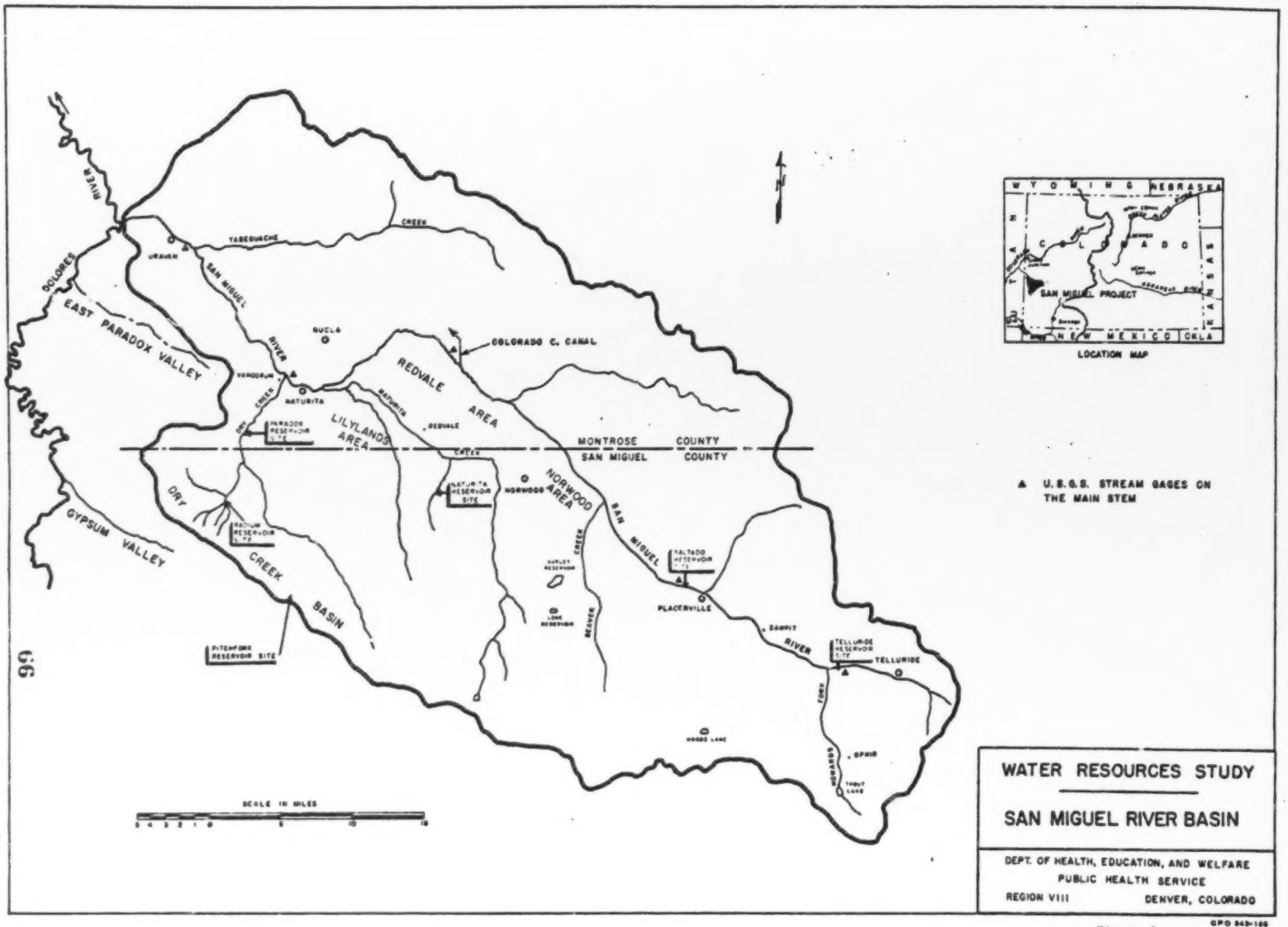

RIVER
DOLORES
EAST PARADOX VALLEY
GYPSUM VALLEY
DRY CREEK BASIN
TABEGUACHE CREEK
URAVAN
SAN MIGUEL RIVER
NUCLA
NARADOR RESERVOIR SITE
NATURITA
NATURITA CREEK
REDVALE
COLORADO C. CANAL
REDVALE AREA
LILYLANDS AREA
MONTROSE COUNTY
SAN MIGUEL COUNTY
NATURITA RESERVOIR SITE
NORWOOD
NORWOOD AREA
SAN MIGUEL
SALTADO RESERVOIR SITE
PLACERVILLE
DISLEY RESERVOIR
LONE RESERVOIR
BEAVER CREEK
DRY CREEK RESERVOIR SITE
PITCHFORK RESERVOIR SITE
DALLAS CREEK
RIVER
TELLURIDE RESERVOIR SITE
TELLURIDE
IDAHO
OPHIR
TROUT LAKE
HOWARDS
VOGEL LAKE
SCALE IN MILES
5 4 3 2 1 0 5 10 15
WYOMING
NEBRASKA
COLORADO
NEW MEXICO
OKLA.
SAN MIGUEL PROJECT
LOCATION MAP
▲ U.S.G.S. STREAM GAGES ON THE MAIN STEM
WATER RESOURCES STUDY
SAN MIGUEL RIVER BASIN
DEPT. OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
REGION VIII
DENVER, COLORADO
GPO 843-166

Figure 1